DCE-1

BACKGROUND DATA COLLECTION
TEST PLAN
Fort A.P. Hill, Virginia
Fort Carson, Colorado

December 23, 1996

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1. Background

Most technologies in use or proposed for use in detecting landmines and unexploded ordnance (UXO) suffer from unacceptably high false alarm rates, even at modest probabilities of detection. Expected signals from mines and UXO are at least moderately well understood, and theoretical models can, in many cases, reliably predict target signatures. In contrast, clutter signatures have not been well studied and, as a result, many false alarm mitigation efforts are conducted in relative ignorance. The goal of this program is to begin to create a better understanding of clutter signatures. Contractors will collect clutter data using the following sensor types: magnetometer, infrared, electromagnetic induction (metal detector), and ground penetrating radar. These sensor types represent the canonical systems in use or proposed for use for detecting landmines or UXO.

2. Objective

The objective of this program is to advance the state of the art in UXO and landmine detection by collecting data to aid in the understanding of the effects of clutter on system performance. The background data collected will also be useful in evaluating detection systems because such evaluations require knowledge of both clutter and target statistics.

To achieve this objective, the backgrounds program will be conducted in two phases:

Phase I - Data collection.
Phase II - Data analysis.

During Phase I, contractors will be asked to survey four sites at two U.S. locations (Fort Carson, Colorado and Fort AP Hill, Virginia). These locations represent three different soil types as depicted in Figure 2.1, and a limited variation in man-made contamination. Initial site inspections suggest that three of the four sites (at the two locations) will have a small amount of man-made contamination. One of the four sites, located at Fort A.P. Hill, has a substantial amount of UXO fragmentation and other debris, but no UXO. In addition to man-made items already existing on the site, a small number of synthetic calibration targets, UXO items, and landmines will be emplaced in selected areas on each site.

	Moist	Dry
SAND	Fort A.P. Hill	Fort Carson
CLAY	Fort Leonard Wood	Fort Carson

Figure 2.1 Soil and moisture variation represented in this experiment.

The contractors will be asked to survey each site at much higher resolution than they might use if the purpose of the survey was to locate UXO. The goal here is to collect high-resolution data over the entire site. This high-resolution data will be used during Phase II of the program to aid in the development of discrimination or sensor fusion algorithms with the goal of substantially reducing the false alarm rate currently exhibited by this set of sensors while not significantly impacting the probability of detection.

Phase II of the program is unique in the sense that Defense Advanced Research Projects Agency (DARPA) will make these data widely available to sensor developers, universities, and other private companies that have an interest in developing improved detection methods or algorithms. DARPA intends to encourage these development activities by providing a subset of the data collected and the corresponding ground truth information to anyone who requests it. In return, DARPA will impose limited requirements on the requester to provide feedback on the type of work being performed and any improvements to sensors or algorithms that result from the data collected. The remainder of the ground truth data, that which are not distributed, will be held by the government to test and evaluate any new or improved algorithms.

3. System Descriptions

Data will be collected using four types of sensors: ground penetrating radar (GPR), electromagnetic induction (EMI), magnetometer, and infrared (IR). Because it was not feasible to bring every variation of each of these sensors to the sites, an attempt was made to select systems that spanned the maturity range of the sensor type. Sensor systems selected range from state-of-the-art to mature in each category.

3.1 Ground Penetrating Radar Systems

Several GPR systems using different frequency bands and different antenna designs were selected to provide data that bracket current technology system capabilities. In addition, a state-of-the-art, ultra-wideband radar from Lawrence Livermore National Laboratories (LLNL) was selected to provide detailed GPR data on a few selected areas. These areas will be determined based on data collected from the other GPR surveys and geophysical data collected at the site.

3.1.1 Coleman Research Corporation

Coleman Research Corporation (CRC) will survey the four sites using two GPR systems. The CRC Towed Multi-Sensor Array System (ToMAS) is an extension of the CRC Earth Penetration Radar Imaging System (EPRIS). The vehicle-mounted GPR utilizes a five element array of frequency stepped wideband radar antennas (100 - 1000 MHz) capable of detecting metallic and nonmetallic objects up to 5 meters deep. Both co-polarized and cross-polarized data wil be collected with this GPR. Data are collected and stored on read/write electromagnetic media (SCSI hard disk) simultaneously while the sensor is pulled behind a tow vehicle. Sensor data are collected by navigating a "sliding oval" pattern moving west to east across the site. Line-to-line spacing is roughly 2.7 m. Position information is collected from an optical encoder mounted to a wheel. Time stamp data is collected from a NAVSTAR GPS system. CRC will also collect data using one of their handheld

radars mounted to the vehicle. The handheld radar operates at a higher frequency (0.7-4.2 GHz) and is intended to detect smaller, shallow objects such as landmines. Complete site coverage with the handheld radar will not be achieved. All of the data collected are stored on two distinct media during the scanning process and are later recalled for post-data processing. CRC uses a data fusion workstation to process and combine the data for two-dimensional and three-dimensional image displays.

3.1.2 GeoCenters

The GeoCenters vehicle-mounted mine detector system has been configured to integrate a suite of sensors. For this experiment, the system will include an infrared (IR) system operating between 4 and 5 μm, a GPR system, and a Trimble 4000 SSI global positioning system (GPS). These systems are mounted on a single field vehicle that incorporates an integrated landmine detection processing system. The concept utilizes a forward-looking (IR) sensor for stand-off (>10 meters) detection combined with a 15-inch vertical stand-off GPR sensor in an automatic target recognition mode. The IR system is described in more detail below in section 3.4.

The current system platform is a Ford 350 with a crew cab. The GeoCenters patented twenty-seven inch wide multi-antenna ground penetrating radar array focuses and sweeps energy into the ground in order to detect buried objects. It is, therefore, termed a Focused Array Radar (FAR). This GPR operates in a frequency range of 700 - 1300 MHz. It is capable of detecting both metallic and nonmetallic landmines and has incorporated a prototype automatic target recognition (ATR) capability. Real-time background subtraction improves false target discrimination. Data from multisensor arrays are integrated in a management and scoring computer, designated as the integration processor (IP). The IP receives signals via RS232 and RS422, locates the targets, scores the target reports, and sends a signal to the target marking array (located on the vehicle) to mark the selected target at the determined target location.

Note: Although the system has ATR capabilities and automatic background subtraction, in this program the data collected prior to the ATR will be recorded for future use.

3.1.3 Lawrence Livermore National Labs

LLNL developed a Calibrated Autonomous Radar Testbed (CART) to collect synthetic aperture radar data in the field. The system is composed of an HP-8510C vector network analyzer attached to an EM System's dual-ridged conical waveguide horn antenna and a control computer. It has the capability of sweeping the frequency band from 45 MHz to 18 GHz, and capturing data at up to 801 discrete frequency steps with better than 40 dB above the environmental noise floor. The radar is continuous wave (CW) in a monostatic cross-polarized mode. The system is phase locked so that complex information is acquired and converted to an equivalent wideband signal. This signal is then fed into the MIR image reconstruction code for processing. The CART system includes a small autonomous vehicle that navigates via computer control and scans an area. As this system cannot

be used to survey large areas, it will be used to "interrogate" only a few areas of interest as identified by the other GPRs used for this program.

3.2 Electromagnetic Induction Systems

Three induction coil systems were selected to survey the site. Both time- and frequency-domain electromagnetic induction (EMI) systems were selected to provide data in multiple modalities and thus investigate various combinations of these modalities for clutter rejection.

3.2.1 Science Applications International Corporation

The Science Applications International Corporation (SAIC) system consists of a one meter wide Schiebel induction coil (IC) array dragged by a four-wheel-drive vehicle.

The one meter wide Schiebel array has eight transmitting and receiving coils that are powered from an electronics unit housed in a standard 19 inch enclosure. The array, rigidly encased in fiberglass, will be operated flush to the ground. The resolution of the sensor is 10 inches. The 12-bit digitized signal will be recorded with respect to position using the compass and GPS location information described below.

The navigation system is composed of a differential GPS and a digital compass. The differential GPS is intended to provide long-range accuracy (on the order of one meter or less). Using the GPS location data, a symbol of the vehicle is displayed in a navigation window and the position of detected targets is recorded. This display of the trajectory of the vehicle in the navigation window, expanded to proper scale, will help the operator ensure complete coverage of the site. If necessary, the stored vehicle location measurements can be curve fitted in post-processing to provide better estimates of the vehicle path and to verify coverage of an area.

The differential GPS consists of an Ashtech Super C/A (Model SCA-12) receiver, with 12 independent channels, and a DCI FM receiver that acquires and passes on to the Ashtech the differential corrections in RTCM format. The Ashtech unit is configured to make code-phase (not carrier-phase) measurements, and can provide latitude and longitude updates once every second. Communication between the Ashtech GPS and the onboard computer is via RS-232. In addition, the SCA-12 can provide other information that can be used to assess the accuracy of the measurements. Differential corrections must be supplied to the Ashtech GPS in RTCM 104 format. SAIC plans to use another Ashtech receiver, placed at a known location, to generate the differential corrections.

The digital compass (Model TCM2 by Precision Navigation, Inc.) provides the heading of the vehicle and is accurate to one-tenth of a degree. The TCM2 combines a three-axis magnetometer and a two-axis tilt sensor. The tilt sensor allows the microprocessor to internally correct the compass indications for tilt. The digital compass is used to plot the symbol of the vehicle in the correct orientation and to calculate the coordinates of a detection.

3.2.2 Parsons

Parsons will employ two handheld EMI systems to survey the test sites. The first system will consist of a 0.5 meter Geonics EM61 pulsed induction sensor equipped with two co-planar 0.5 m coils with a vertical spacing of 0.4 m. Line spacing for this system will be 0.5 m and data will be collected at 0.2 m intervals along survey lines. The sensor height above ground level is approximately 0.3 m.

The second EMI system is a Geonics EM61-3D three-component, time-domain sensor. The system consists of a multichannel pulsed induction system having a 1-m square transmitter coil and three orthogonal 0.5 m receiver coils positioned approximately 0.3 m above the ground. The system operates at a base frequency of 7.5 Hz. Sensor output is measured and recorded at 20 geometrically spaced time gates, covering a time range from 320 μs to 32 ms. Data will be collected along survey lines spaced 1 m apart at a rate of 3 samples (60 time gates) per second.

3.2.3 Geophex

Geophex will employ handheld EMI and magnetic gradiometer systems. The EMI system is the GEM-3 monostatic, multifrequency sensor that can operate at frequencies in the range of 300 Hz to 20,000 Hz. Geophex will survey the sites at multiple EMI frequencies (determined at each test site) and will provide in-phase and quadrature EMI maps. The system is capable of operating either in a frequency-domain or time-domain mode and can be used to image the three-dimensional distribution of the induced magnetic signal of the buried objects. Only frequency domain data will be collected with the GEM-3. Spatial data density of the surveys will be 1.0 m by 0.5 m or better.

3.3 Magnetometer Systems

Two magnetometer systems were selected. Both time and frequency domain electromagnetic (EM) systems were selected to provide data in multiple modalities at the sites.

3.3.1 Geometrics

Geometrics will employ handheld G-858 gradiometer systems; each consists of two self-oscillating, split-beam Cesium vapor magnetometers spaced 0.5 meters apart. The sensors have an operating range of 17,000 nT to 100,000 nT (gamma) with a resolution of 0.05 nT peak-to-peak at a 0.1 second cycle rate. Systems heading error is less than ± 0.5 nT. Data from each of the two sensors are recorded at 10-Hz along with GPS time and operator-marked fiducial points. Multiple surveys will be conducted with the sensors oriented horizontally and vertically at a height of 0.5 meters as measured from the ground to the mid-point between the sensors. Lane spacing will be 1 meter and data will be collected at approximately 10 cm along-track spacing. Additional surveys will be conducted with the sensors separated by 1 m, in a horizontal gradient mode and at 1 m height.

3.3.2 Geophex

The magnetic gradiometer system is a handheld G-858 Cesium vapor gradiometer configured to collect vertical magnetic gradient information. Geophex will provide total field magnetic maps, and vertical gradient magnetic maps. Spatial data density of surveys will be 1 m by 0.5 m or better.

3.4 Infrared Systems

3.4.1 GeoCenters

The GeoCenters IR system consists of an Amber Radiance 3-5 μm camera that is mounted on top of their IGMMDT vehicle. It looks forward and has roughly a 20 degree depression angle. The frame grabber acquires the data at a 3.5 Hz rate for periods of up to 5 minutes with 14-bit precision. The image size is 256 x 256 pixels. Real-time display of the data is possible.

3.4.2 SAIC

The SAIC IR system consists of an 3-5 μm Amber Radiance camera that is mounted on top of a Ford Explorer on a boom that holds the camera approximately 15 feet above the ground. The camera has square field of view looking straight down on the drivers side of the vehicle. The image size is 256 x 256 pixels. Real-time display of the data is possible.

4. Test Sites

Two U.S. locations (Ft. Carson, Colorado, and Ft. A.P. Hill, Virginia) have been selected for the background clutter data collection experiment. Four sites were selected—two at each location. These sites represent different soil types, Figure 2.1, and different amounts of existing man-made clutter. The intent is to collect data over a range of environmental conditions to assess the relative effect of both natural clutter and existing man-made debris on the various sensors.

4.1 Fort A.P. Hill, Virginia

Data will be collected at two different sites at Fort A.P. Hill. A map showing Fort A.P. Hill in relationship to Richmond, Virginia, and Washington D.C. is provided in Appendix C. Due to the human activity at Fort A.P. Hill since World War I, both of these sites are cluttered with shrapnel and other metallic debris. One site, Firing Point 20, is highly cluttered, while the other site, Firing Point 22, contains less clutter.

4.1.1 Terrain

Both sites at Fort A.P. Hill consist of upland ridges and side slopes. The composition of the soil is emporia fine sandy loam with 2-6 percent grade slopes. Beginning at the surface, a typical soil profile consists of 0-6 inches of dark brown fine sandy loam, followed by 6-12 inches of light yellowish brown fine sandy loam. The next 12-24 inches consists of yellowish brown sandy clay loam with brownish yellow mottles, followed by 24-39 inches consists of strong brown sandy loam with yellowish brown, pale brown, and light brownish gray mottles.

The water table is low in the uplands and high in the stream valleys.

Soil properties and qualities are as follows:

- Depth - very deep.
- Drainage class - well drained.
- Seasonal high water table - 36-54 inches.
- Permeability - moderate or moderately slow.
- Available water capacity - moderate.
- Shrink-swell potential - low to moderate.

4.1.2 Climate

Fort A.P. Hill experiences an average of 43 inches of precipitation annually. The tables below are climatological averages collected at Corbin, Virginia, which is located near Fort A.P. Hill.

Climatological Normals (1961-1990)

Temperature (°F)	August	September	October	November
Average	75	68	57	48
Maximum	86	79	69	59
Minimum	64	57	45	36

Precipitation (inches)	August	September	October	November
Average Precipitation	4	3.5	3.7	3.4
Average Snow	0	0	0	0.7

4.2 Fort Carson, Colorado

The tests at Fort Carson will be conducted at two sites. Fort Carson is located in between Colorado Springs and Pueblo. A map showing Fort Carson in relationship to Denver and Colorado Springs and the two sites in relation to each other are provided in Appendix C.

4.2.1 Terrain

Fort Carson consists of uplands that are spatially variable: clay, sand, and rock. The water table is low. The area's many stream valleys are characterized by stratified clay, silt, sand, gravel and cobbles. The stream valleys also have low water tables.

4.2.2 Climate

Fort Carson is characterized by a dry climate with an average of 16 inches of annual precipitation.

Temperatures at Fort Carson, Colorado

Temperature (°F)	August	September	October	November
Average maximum	83	73	62	51
Average minimum	60	51	41	31

Precipitation at Fort Carson, Colorado

Rainfall (inches)	August	September	October	November
Average	2.5	1.0	0.6	0.6*
Maximum recorded	not provided	4.8	6.0	not provided

* Average 4" of snow in November.

5. Test Preparation

This program is a data collection effort and is not intended to test the detection capabilities of any of the participating systems.

The test preparation includes making arrangements for the execution of the test, characterizing the sites selected; placing fiducial markers on the site to aid in navigation, obtaining equipment to aid in test execution; and fabricating, obtaining, and emplacing targets. The site characterization, setup, UXO target and mine acquisition, and target emplacement tasks will be performed by personnel from the Waterways Experiment Station (WES) in Vicksburg, Mississippi. Night Vision Electronic Sensors Directorate (NVESD), Virginia will provide some of the mines and the targets that were fabricated specifically for this experiment.

5.1 Site Characterization

WES will perform a comprehensive site characterization of the test sites at both Fort Carson, Colorado and Fort A.P. Hill, Virginia prior to the installation of registration targets, calibration sources, UXO, and mine targets. The effort will result in benchmark documentation of the sites for contractor system survey planning, results assessment, and data analysis. The site characterization will provide archival documentation for any future use of the sites and for comparing this investigation to past and future UXO/mine detection investigations.

The objective of the site characterization is to determine:

- Details of geology.
- Important geophysical parameters.
- Site heterogeneity.
- Environmental parameters.

5.2 General Approach

Site characterization involves the following activities:

- General site layout and marking.
- Geologic investigations.
- Soil sampling and analysis.
- Geophysical investigations
    - ◊ Seismic refraction surveys (P- and S-wave)
    - ◊ Electrical resistivity soundings.

- ◊ Ground penetrating radar surveys (profiles and WARR/CMP).
- ◊ Magnetic surveys (total field and total field vertical gradient).
- ◊ EMI survey.
- ◊ Integrated interpretation.

- Topography and vegetation characterization.
- Meteorological data collection.
- Soil temperature, target temperature, and soil moisture data collection.

Each of these activities is described in greater detail in the following sections.

5.2.1 General Site Layout and Marking

Each of the four data collection sites will be laid out in a rectangle as shown in Figure 5.2a. Firing Point 22 at Fort A.P. Hill had to be redesigned due to conditions at the site. The center portion of the site was too wet and muddy to be used. See Figure 5.2b for the layout of Firing Point 22. The origin will be marked with an aluminum hub placed in concrete, after all contractor surveys have been completed. A local reference system will be used, with all measurements referenced to the origin ([0,0] point). Plastic stakes will be placed every 5 m along the perimeter of the 100-m x 100-m site and along the Side Bars. Each stake position will be determined by using survey equipment. A plastic flag will be placed at each stake. Both the flag and the stake will be annotated with its location relative to the origin (i.e., the stake at the origin (southwest corner) will be labeled (0,0) and the one at the northeast corner will be designated (125,100)). Figure 5.3 shows where the stakes and flags will be located on each site.

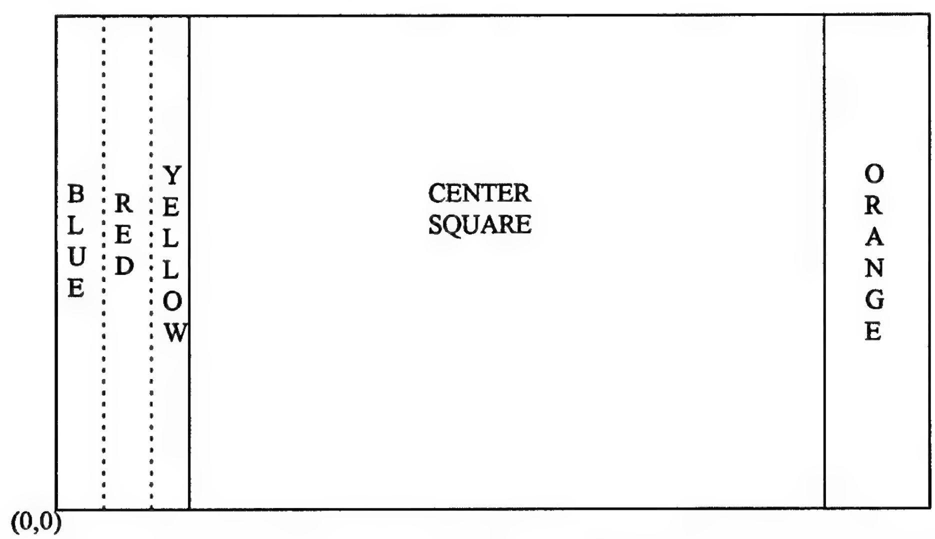

Figure 5.3 Stakes and flags are placed every 5 meters along each solid line in shown in the drawing.

Registration targets located within the Center Square will be positioned and surveyed prior to conducting the topographic surveys. The center of each registration target cluster will be marked by two red flags. The background

characterization studies will be performed in the Center Square area. The Calibration Area and Side Bars will contain buried UXO targets, mine targets, and calibration sources.

5.2.2 Geologic Investigations

A review of the geologic literature for the Fort Carson and Fort A.P. Hill areas will determine the general geologic settings in terms of physiography and geomorphology, soil and rock types, groundwater levels, and general stratigraphy and structure. Geologic reconnaissance and examination of geologic and soil maps will determine details for the specific sites relative to the general settings.

5.2.3 Soil Sampling and Analysis

Soil samples will be taken at the registration target locations shown in Figure 5.2a. Samples will be obtained at the surface and to depths of approximately 3 m; a minimum of three samples to be taken per registration location. The samples will be immediately placed in sealed containers to preserve water content. The samples will then be visually classified by a geologist and/or soil scientist. A minimum of one sample per location will be selected for further analysis in the WES Soils Testing Laboratory to determine water content, soil type (physical classification according to Unified Soil Classification System), index tests, particle gradation, and qualitative mineralogy (Corps of Engineers, 1960; Means and Parcher, 1963). A dielectric permittivity, both e' and e" as a function of frequency and water content, which yields estimates of EM wave speed and electrical conductivity (Simms and Butler, 1995; Curtis, et al., 1995). Further, at a minimum of one location per Center Square, a profile of both e' and e" as a function of depth, frequency, and water content will be constructed. The other four registration point samples will be used to measure the dielectric constant using only the first 10 cm of soil.

5.2.4 Geophysical Investigations

Physical concepts of the geophysical methods are presented in several standard texts, e.g. Telford, et al., 1990, and Corps of Engineer publications, e.g., Corps of Engineers 1979, 1995. Field procedures and the rationale for planning and executing site characterizations are discussed in numerous WES and other technical publications, e.g., Corps of Engineers, 1979, 1995; Butler 1994a,b. The Corps of Engineers and WES have extensive experience in planning, executing, and documenting site characterizations in all 50 U.S. states, in many foreign locations, and for numerous and diverse sponsors and objectives (Butler, et al., 1988). Figure 5.4 serves as a generic reference for descriptions of all planned geophysical surveys. Four survey profile lines and several point locations are indicated in Figure 5.4. Each geophysical survey method is discussed below in terms of objectives, procedures, equipment, and accuracy.

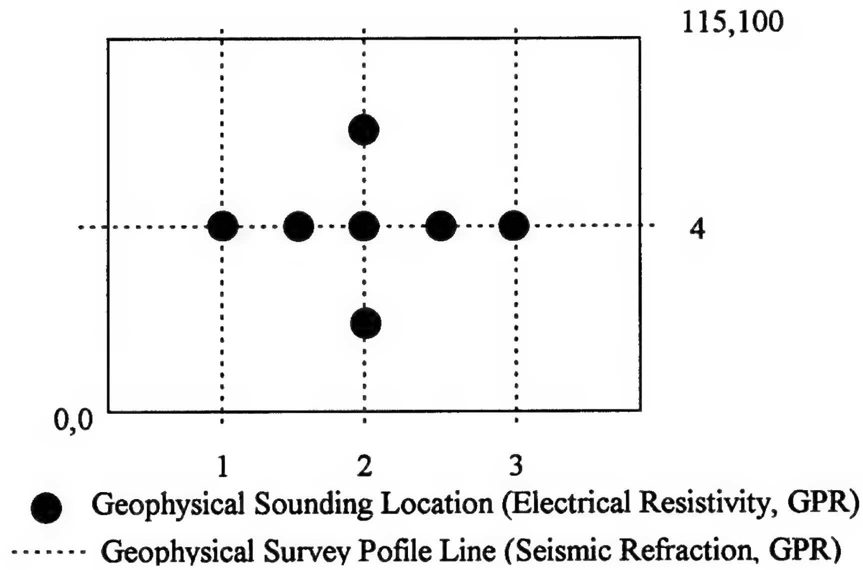

Figure 5.4 General site plan for geophysical survey profile and "sounding" locations.

5.2.5 Seismic Refraction

Objectives

- To determine depth to saturated material.
- To determine thickness of subsurface layers with contrasting seismic velocities.
- To determine "topography" of interfaces between layers.
- To determine P- and S- wave seismic velocities.

Procedures

Four survey lines will be measured, as shown in Figure 5.4. The geophone spacing will vary from 0.5 m to 3 m. The investigation will penetrate to approximately 10 m. Data will be interpreted using WES's SEISMO and RIMROCK's SIPT software. The final product will be two-dimensional cross sections along each of the four survey lines.

Equipment

Equipment includes the following: 24 channel EG&G seismograph, 8 Hz geophones, hammer (impulsive) source or explosives (if needed).

Accuracy

- Interpreted depths to interfaces are accurate to better than 10 percent of the depth.
- Interpreted seismic velocities are accurate to 5 percent of the velocity or better (dependent on the heterogeneity of the site).

5.2.6 Vertical Electrical Resistivity Soundings (VES)

Objectives

- To determine depth to the phreatic zone.
- To determine depth to layers with contrasting electrical properties (e.g., sand versus clay).
- To determine electrical resistivity (inverse of conductivity) of subsurface materials.

Procedures

The planned investigation will penetrate to approximately 10 m. Five VES are planned in two intersecting lines. Inversion will be accomplished using INTERPREX software. The final product will be a vertical electrical profile (i.e., electrical resistivity versus depth a five locations along two intersecting lines).

Equipment

Equipment includes the following: ABEM SAS 300B or STING electrical resistivity meter and Schlumberger array.

Accuracy

- Interpreted depths to interfaces are typically accurate to 10 percent of depth.
- Interpreted resistivities are typically accurate to 10 percent of resistivity.

5.2.7 Electromagnetic Magnetic Surveys

Objectives

- To determine terrain (apparent) electrical conductivity distribution over the site.
- To determine volume averaged electrical conductivity of subsurface materials.
- To measure quadrature phase (conductivity) and in-phase (sensitive to metallic objects) components of EM field.

Procedures

Measurements will be taken every 0.5 m along lines spaced 2 m apart. The nominal depth of investigation is 5 m.

Equipment
This investigation uses the Geonics EM31, which operates at 9.8 kHz. The conductivity ranges from 1 mS/m to greater than 1000 mS/m. The noise levels are reported to be 0.1 mS/m quadrature and 0.03 ppT in-phase. The final products are contour maps of conductivity (mS/m) and in-phase response (ppT).

Accuracy
Typical measurement accuracy is 5 percent at 20 mS/m.

5.2.8 Magnetic Total Field and Total Field Vertical Gradient Surveys

Objectives

- To measure the local earth's magnetic field strength and its vertical gradient.
- To characterize any local/regional trends prior to any site disturbance.
- To locate any "large" buried ferrous-metallic objects prior to site disturbance.

Procedures:
Measurements will be taken every 0.5 m along lines spaced 1 m apart. Final products are diurnal and base station reference value-corrected contour maps of magnetic total field and total field vertical gradient in nT and nT/m, respectively.

Equipment:
Equipment for this investigation includes a GSM 19T proton precession magnetometer with a range of 18,000 to 120,000 nT.

Accuracy
Typical measurement accuracy is ±1 nT. Sensitivity is ±0.2 nT.

5.2.9 Ground Penetrating Radar Surveys

Objectives

- To determine subsurface stratigraphy and assess heterogeneity.
- To detect material layers and other objects with contrasting electrical/dielectrical properties.
- To determine EM wave speeds and bulk dielectric permittivity.

Procedures
Four lines will be surveyed as shown in Figure 5.4. The investigation will be conducted at 50 MHz, 200 MHz, and 900 MHz frequencies. The depth of the investigation is a function of the antenna frequency and the antenna design but is expected to be on the order of 10 cm to 10 m. The transmit and receive antenna spacing will be held fixed depending on the frequency and the desired depth of investigation. The emphasis in this experiment is on the uppermost 2 meters of soil. WARR/CMP soundings will be taken to determine EM wave speeds as function of

frequency, site location, and bulk dielectric permittivity (at the sounding locations indicated in Figure 5.4.)

Equipment

- Systems and Software, Inc., PulseEKKO IV/100 and/or PulseEKKO 1000 (pulsed or time-domain GPR's).
- Systems and Software, Inc., data processing software and USGS/WES full waveform modeling capabilities.

5.2.10 Data Integration and Site Characterization Documentation

The electrical resistivity, GPR, and soil sample analysis results will be integrated to form geologic cross sections of the sites, e.g., Butler, et al. 1996. Detailed analyses of the GPR results will give a qualitative high-resolution assessment of shallow geologic heterogeneity, detailed shallow stratigraphy, and location and assessment of localized features (Butler, et al., 1994; Butler, 1992). The magnetic total field, magnetic vertical gradient, EM terrain conductivity, and EM in-phase results will give an assessment of (1) the presence of shallow, buried "large" ferrous-metallic objects (0.25 m scale or larger), (2) the presence of metallic or other localized conducting zones, (3) the variation of bulk conductivity across the sites, and (4) the local regional variation of the magnetic field across the sites.

Note: Buried small ferrous-metallic and other metallic objects such as nails or debris will not be removed from the site; these items are considered to be a part of the background for this study. Data from the site characterization will be made available to the contractors as they become available. An initial hard copy of the data package will be prepared and distributed prior to contractor field work; the final site characterization report to be presented to all participants at a later date. Measurement data will also be available in electronic form on 3.5" floppy disk media in accordance with the Background Standard Format (BSF) described in Appendix B.

5.2.11 Topography and Vegetation Characterizations

Topography data collection will commence once the geophysical site characterization has been completed for each site. The topography data collection effort will consist of an extensive site survey to accurately depict the micro-topography of each site. Any man-made features, visible geologic anomalies, (rocks, anthills, etc.), emplaced targets, and the location of instrumentation will also be surveyed at this time. Vegetation characterization will be done jointly with the geophysical characterization and will consist of delineating major vegetation types (grasses, shrubs, trees, bare soil, and other vegetation) and measuring stem densities. Vegetation densities will be measured using the standard density grid system. All measurements will be obtained using a combination of GPS and terrestrial survey methods/techniques. All data will be processed, plotted, and field checked to ensure accuracy. Gridded data files will then be generated and provided to the data management team. All data will be provided in BSF providing the X-Y-

Z data and a descriptor for each point. All data will be delivered to the background team (BT) prior to commencement of contractor background measurement activities.

5.2.12 Meteorological Data Collection

WES will deploy a meteorological field station at the Firing Point 20 site at Fort A.P. Hill and at the Turkey Creek site at Fort Carson. These two stations will be erected prior to the start of contractors' data collection exercise and will be configured to collect data on air temperature, relative humidity, barometric pressure, solar radiation, wind speed, wind direction, and precipitation (tipping rain buckets). Each station will sample these parameters at 1-minute intervals and calculate a 5-minute average to be stored. All data will be downloaded from the station at regular intervals (minimum once per 24 hours, maximum once per hour) and will be monitored at the field site and plotted graphically on a continuous 24-hour display. All data will be quality checked using the display and any suspect data/sensor readings will be noted and verified. Data will be delivered weekly to the BT. All data will be stored in comma delimited ASCII files with the following format:

Site: Turkey Creek, Seabee, Firing Point 20, or Firing Point 22
Program: Data logger Program Number
Year: 1996
Julian Date: Day of Year
Time: 24 hour local time
Air Temp: Air Temperature (°C)
Rel Humid: Relative Humidity (%)
Bar Press: Barometric Pressure (mBars)
Solar Rad: Solar Radiation (W/meter square)
Wind Speed: Wind Speed (m/s)
Wind Dir: Wind Direction (°N)
Precip: Precipitation (mm)

The weather station will also contain a telemetry system for transferring the data to the field office. As much as possible, telemetry links will be established between all instrumentation stations and the field office or weather station.

5.2.13 Soil/Target Temperature Data and Soil Moisture Data Collection

Two instrumented field stations will be deployed to collect temperature and soil moisture data from the calibration areas at each site. In addition, some areas of the soil outside of the site will be monitored. Up to 24 thermistors will be deployed at each site to collect target and soil temperature measurements. The target temperature measurements are described in section 5.4. Four soil moisture probes will be deployed at each site to collect soil moisture as a function of depth. The soil moisture probes will be deployed at depths from just below the surface to a depth of 1 m at 0.3 m intervals. The soil moisture probes will be deployed as soon as the GPR/EM characterizations are completed so that field calibrations may be performed and data quality check prior to start of data collections. The soil

moisture probes and the thermistors will be sampled at 1-minute intervals and averaged for 5-minute outputs. Data will be stored in comma delineated ASCII files. Data format will be as follows:

Field Station 1

Site: unique site designator
Program: Data logger program number
Year: 1996
Julian Date: Day of Year
Time: 24 hour local time
Channels 1-16: soil temperature (°C)

Field Station 2

Site: unique site designator
Program: Data logger program number
Year: 1996
Julian Date: Day of Year
Time: 24 hour local time
Channels 1-8: soil temperature (°C)
Channels 9-16: soil moisture percent H_2O by volume
precip: Precipitation on site away from meteorological field station

Data will be downloaded from the stations at regular intervals (minimum once per 24 hours, maximum once per hour) and plotted as a 24-hour graph to ensure quality control and proper sensor operation. Any suspect data will be noted and verified. All data will be transmitted weekly to the BT.

5.2.14 Schedule of Site Characterization Activities

A timeline for site preparation and characterization activities is presented below. This timeline applies to activities at both Ft. A.P. Hill and Ft. Carson.

Day	Site Characterization Activities
1	Complete layout and marking of site 1 and begin geophysical investigations.
2	Complete layout and marking of site 2 and begin vegetation characterization and assembly of meteorological field stations at both sites
7	Complete geophysical investigations of site 1; begin geophysical investigations of site 2; begin target deployment, soil sampling, topographic survey, target survey, and instrumentation for site 1
10	Complete target deployment, soil sampling, topographic survey, and checkout of instrumentation for site 1.
14	Complete geophysical investigations of site 2; begin target deployment, soil sampling, topographic survey, target survey, and instrumentation for site 2.
17	Complete target deployment, soil sampling, topographic survey, and checkout of instrumentation for site 2.
28	Complete data reduction and furnish results to BT and contractors.

5.3 Registration, Side Bar, and Calibration Targets

Figure 5.2a illustrates the overall test site. The site measures 125 m by 100 m. Each site consists of three areas:

1. The Center Square, where the background clutter data will be collected. The Center Square contains five groups of registration targets described in section 5.3.1. This area measures 100 m x 100 m.

2. The Side Bars, which contain real targets and target surrogates that can be more easily modeled. The Blue Side Bar measures 100 m x 5 m, the Yellow Side Bar measures 100 m x 3 m, and the Orange Side Bar measures 100 m x 5 m. Portions of the Blue and Yellow Side Bars are set aside for system calibration.

3. The Calibration Area, which contains portions of the Blue and Yellow Side Bars and a Red lane. The calibration area contains (1) the same three registration targets, in the same configuration, as found in the Center Square, (2) targets that can be used for system tuning, and finally, (3) targets that are difficult to detect (system stressing targets) to ensure that the system settings have desired sensitivity before surveys begin. The total Calibration Area (Red, Yellow, and Blue portions) is 30 m x 15 m.

5.3.1 Registration Targets

The clutter data will be collected in the 100-m x 100-m section of the site, termed the Center Square. Five groups of registration targets will be placed in surveyed

locations in the Center Square. These targets are selected with the intent that each of the sensors will easily observe at least one of the registration targets at each location. The registration targets permit the sensor data sets to be referenced to a known coordinate system and mutually registered. To assure consistency, the same registration and calibration targets will be used at both Ft. Carson and Ft. A.P. Hill

Each registration location contains the same three targets. The three registration targets used for this test are as follows:

- Registration Sphere—4.875-inch iron sphere[1] buried at a depth of 10 cm. This is the registration target for both the magnetometers and EMI systems. The sphere will be demagnetized prior to emplacement. An estimate of the signature is approximately 92 γ (peak) for a full field magnetometer (geofield corrected) and approximately 22 mV peak voltage for an EM-61. These signatures are estimated assuming the sensor is at a reference height of 0.5 m. Both estimated signatures should be tested on a limited number of targets prior to emplacement to assure that these estimates are accurate.
- Registration Large Aluminum Plate—an 8-inch square, 1 inch thick, aluminum plate buried at a depth of 5 cm. This target is intended to insure that both the high- and low-frequency GPR systems will register a measurable signal when the GPR sensor passes over the target. It is emplaced at a shallow depth to ensure that the high frequency GPR radars in wet soil conditions (possible at A.P. Hill) will be able to achieve the penetration necessary for detection.
- Registration Small Aluminum Plate—a 4 inch square, 1/2 inch thick, aluminum plate placed on the surface. This registration target is used for IR sensors. The Aluminum plate will be placed on the surface between the surveyed location of the two buried registration targets, which will be marked with paint. The IR registration targets will be on the site only when the IR sensors are surveying. They will be moved and replaced during the survey as necessary to avoid interference with other sensors.

5.3.2 Calibration Area

Each site will have a calibration area. The 30 x 15 meter calibration area is divided into three lanes, labeled Red, Blue, and Yellow, as shown in Fig 5.5.

- The RED Side Bar contains a copy of the registration targets, other targets for calibration, and the system stressing targets. The registration targets are for all contractors. The remainder of the red lane contains targets to calibrate radar and electromagnetic induction systems and system stressing targets to determine whether these sensors are achieving the sensitivity desired for the background data collection.

[1] Spheres are 16-pound shots used for shot putting.

• The YELLOW Side Bar contains mines, infrared calibration sources, and dielectric targets. This lane is to be surveyed by all systems intended to detect mines, i.e., all systems other than the magnetometers. The geometrical shapes are intended to provide signatures that can be readily modeled.

• The BLUE Side Bar contains UXO and demagnetized spheres. This lane is to be surveyed by all systems intended to detect UXO, particularly the magnetometers. The geometrical shapes are intended to provide signatures that can be readily modeled.

The targets are described below.

5.3.2.1 Red Calibration—Registration Targets and Stressing Targets

The first three calibration targets in the red lane are arranged in a pattern that is identical to the registration targets (the same depth, orientation, and order). The IR registration target will only be on the site when an IR system is surveying. Magnetic signatures are calculated assuming an induced signature with the geomagnetic field amplitude of 50,000 γ and an inclination of 65 degrees. The EM-61 estimates are taken from Barrow, et al. (Barrow, 1996). The magnetometer signature estimates are made using the method described by Altshuler (Altshuler, 1996). If possible, prior to and after emplacement (at the first site), the signatures of a few reference items will be measured to establish an accurate knowledge of the baseline signature. This measurement is particularly useful for the EMI systems and magnetometers because the soil conditions are, for the most part, less critical and less likely to affect the in situ signatures.

RED-1, **RED-2** and **RED-3** are exactly the REGISTRATION SPHERE, REGISTRATION SMALL ALUMINUM PLATE, and REGISTRATION LARGE ALUMINUM PLATE as described above. *The LARGE ALUMINUM REGISTRATION PLATE also serves as the system stressing target for IR systems.*

RED-4 8-inch-square, 1 inch thick, Aluminum plate buried at a depth of 25 cm to the top. This calibration target should be seen by GPR and EMI, and is similar in size, shape, and burial depth to a metal-cased antitank mine.

RED-5 8-inch-square, 1 inch thick, nylon plate buried 20 cm to the top. The inability to distinguish this target, which will have an RCS similar to a mine of comparable size, indicates that we are not collecting data at 20 cm depth. It is of interest to get some data to a depth of 20 cm from the high-frequency GPR systems. (Other systems are not expected to see this target.) *This is the designated stressing target for higher frequency GPR systems.*

RED-6 15-inch-square, 1 inch thick, aluminum plate buried 100 cm to the top of the plate. The RCS of the aluminum plate will be similar to that of UXO at one

meter. The inability to detect this target indicates that we are not collecting data at a depth of one meter. Because the site characterization needs to be completed to at least one meter, detection of this target is critical. *This is the designated stressing target for lower frequency GPR systems.*

RED-7 10-inch-diameter, Aluminum spherical shell (1/8 inch thick) at a burial depth of 60 cm to the top of the sphere. The EMI signature is predicted to be on the order of 5 mV peak (EM-61) assuming a measurement height of 0.5 m. This is about a factor of five greater than typical system noise (EM-61), (Barrow et al. 1996). Both RED 8 and RED 7 are included because of the difference in signature caused by two orders of magnitude difference in permeability. Note that the peak signature is 5 mV for both. But RED 7 will decay faster in the TDEMI (time domain electromagnetic induction) systems even with the higher conductivity because of the difference in the relative permeability between aluminum and iron. Thus for the EM-61 there will be a different signature over the integration window. For the multiwindow TDEMI system the decay curve is very different, and for the FDEMI the phase shift and amplitude differ between RED 8 and RED 7. Future measurements from this target will provide some ability to compare the three types of EMI systems that will be surveying at the sites. *This is the designated stressing target for the EMI systems.*

RED - 8 4.875-inch-diameter demagnetized iron sphere, buried at a depth of 55 cm to the top of the sphere. The signature for the magnetometer is predicted to be approximately 10 γ. The EMI signature is predicted to be on the order of 5 mV peak (EM-61). Both calculations assume a measurement height of 0.5 meters. This target should not be exceptionally hard to discriminate in a quiet environment, however, in a noisy environment, this target presents a reasonable goal for magnetometer systems. Both magnetometers and EMI sensors should have sufficient sensitivity, but this target will stress the ability to discriminate the target from the background. The magnetometer systems have a large dynamic range and good sensitivity. This target is used to give the contractors a discrimination hurdle, not a sensitivity floor. *This is the designated stressing target for magnetometer systems.*

5.3.2.2 Blue Calibration—UXO and Iron Spheres

The Blue calibration lane is designed to provide an opportunity for contractors with appropriate sensor modalities to calibrate their instruments on actual UXO that has been made safe. Three different types of UXO are placed at different depths and orientations to provide targets with similar maximum signatures as measured by a full-field magnetometer. The target signatures are estimated using a prolate spheroidal model of the ordnance, and corrected for the fact that UXO is not a solid ferrous object.

BLU-1 4.875-inch-diameter demagnetized iron sphere. Burial depth is 35 cm to the top of the sphere. This item is emplaced to provide additional information on

a well characterized and modeled calibration target. The signature for this item should be approximately 25 γ. The peak EMI signature (EM-61) is predicted to be approximately 10 mV.

BLU-2 81 mm mortar (demagnetized) buried to a depth of 30 cm to the top of the ordnance. The orientation is inclination 90 degrees. The predicted signature, approximately 45 γ, is determined by modeling a prolate spheroid with dimensions of 23 cm in length and 8.1 cm in diameter. The maximum signature is reduced to 80 percent to account for hollow ordnance and the large opening in the ferrous shell for the Aluminum fuzing mechanism.

BLU-3 152 mm projectile (demagnetized) buried to a depth of 70 cm to center of volume. The orientation is inclination 0 degrees, declination 90 degrees. The predicted signature, approximately 45 γ, of the 152-mm projectile is determined by modeling a prolate spheroid with dimensions of 48 cm in length and 15.2 cm in diameter. The maximum signature is reduced to 90 percent to account for hollow ordnance.

BLU-4 105 mm projectile (demagnetized) buried to a depth of 55 cm to the top of the ordnance. The orientation is inclination 0 degrees, declination 0 degrees. The predicted signature, approximately 45 γ, of the 105-mm projectile is determined by modeling a prolate spheroid with dimensions of 48 cm in length and 10.5 cm in diameter. The maximum signature is reduced to 90 percent to account for hollow ordnance.

5.3.2.3 Yellow Calibration—Mines and Dielectric Targets

The Yellow calibration lane is designed to provide an opportunity for contractors with appropriate sensor modalities to calibrate their instruments on actual (not live) mines and mine-like targets of regular geometrical shapes that can be modeled. Mine depths are measured to the tops of the mines and are consistent with burial doctrine.

YEL-1 0.5-gram copper disk embedded in a nylon cylinder measuring 7.62 cm in diameter and 2.54 cm in height. The target will be buried at a depth of 2 cm to the top of the disk. Dimensions of the copper disk are 0.465 cm diameter, and 0.233 cm in height. Copper is electrorefined copper of known conductivity. This target gives higher frequency radars the opportunity to interrogate a mine simulant with a known dielectric constant and a metallic surrogate for a fuzing mechanism.

YEL-2 0.39-gram 304 stainless steel (SS) disk embedded in a Teflon cylinder measuring 7.62 cm in diameter and 2.54 cm in height. The target will be buried at a depth of 2 cm to the top of the disk. The SS disk dimensions are 0.159 cm diameter and 2.54 cm height. The conductivity of the SS is known. This target

gives the higher frequency radars the opportunity to interrogate a mine simulant with a known dielectric constant and a metallic surrogate for a fuzing mechanism.

YEL-3 18-cm diameter, 2.54 cm thick, solid Teflon disk, buried 10 cm to the top of the disk. The relative dielectric constant is 2.1 and density is 2.2 g/cm^3. This represents a lower limit for the relative dielectric constant of explosives. This target serves as a large shallow object that should be seen by both the lower and higher frequency radars. The geometry and known dielectric constant permit modeling of the signature.

YEL-4 18 cm diameter solid nylon disk 2.54 cm thick, at a burial depth of 10 cm to the top of the disk. The relative dielectric constant is 3.0 and density is 1.15 g/cm^3. This is an upper limit for the relative dielectric constant of explosives. This target serves as a large shallow object that should be seen by both the lower and higher frequency radars. The geometry and known dielectric constant permit modeling of the signature.

YEL-5 8-inch-square, 1" thick, painted (black) aluminum plate placed on the surface exposed to solar heating. The plate will be monitored by a thermistor for temperature measurement. This target provides absolute calibration for the infrared sensors in the temperature range of interest.

YEL-6 8-inch-square, 1" thick, painted (white) aluminum plate placed on the surface exposed to solar heating. The plate will be monitored by a thermistor for temperature measurement. This target provides absolute calibration for the infrared sensors in the temperature range of interest.

YEL-7 M19 low metallic antitank (AT) mine buried at 15 cm depth to top of mine. Because the mine does not contain any explosive material, the mine is filled with training filler (hard red wax) that closely matches the dielectric properties of HE in the frequency regime of the radar systems. Either a real fuze or a metallic surrogate is added to assure correct metal content.

YEL-8 M14 low metallic antipersonnel (AP) mine buried at 2 cm depth to top of mine. Because the mine does not contain any explosive material, the mine is filled with paraffin wax that closely matches the dielectric properties of HE in the frequency regime of the radar systems. Either a real fuze or a metallic surrogate is added to assure correct metal content.

YEL-9 OZM-3 metallic AP mine buried at a depth of 4 cm to the top of the mine. The mine does not contain any explosive material, but is filled with sand.

5.3.3 Registration and Calibration Target Locations

The following table summarizes the items emplaced in the calibration area and indicates the location and depth of burial. The location is provided in meters to the

east and north of the origin as depicted in Figure 5.2a. It also lists the locations and depths of the registration targets.

Target ID	Description	East (m)	North (m)	Depth to Top (cm)
REG-1-1	Fe sphere	27.5	73	5
REG-1-2	Al plate (4"x4"x0.5")	27.5	75	surface
REG-1-3	Al plate (8"x8"x1")	27.5	77	5
REG-2-1	Fe sphere	40.0	23	5
REG-2-2	Al plate (4"x4"x0.5")	40.0	25	surface
REG-2-3	Al plate (8"x8"x1")	40.0	27	5
REG-3-1	Fe sphere	52.5	85.5	5
REG-3-2	Al plate (4"x4"x0.5")	52.5	87.5	surface
REG-3-3	Al plate (8"x8"x1")	52.5	89.5	5
REG-4-1	Fe sphere	65	10.5	5
REG-4-2	Al plate (4"x4"x0.5")	65	12.5	surface
REG-4-3	Al plate (8"x8"x1")	65	14.5	5
REG-5-1	Fe sphere	77.5	60.5	5
REG-5-2	Al plate (4"x4"x0.5")	77.5	62.5	surface
REG-5-3	Al plate (8"x8"x1")	77.5	64.5	5
RED-1	Fe Sphere	8	1	5
RED-2	Al Plate (8"x8"x1")	8	5	5
RED-3	Al Plate (4"x4"x0.5")	8	3	surface
RED-4	Al Plate (8"x8"x1")	8	11	25
RED-5	Nylon plate (8"x8"x1")	8	14	20
RED-6	Al Plate (15"x15"x1")	8	17	100
RED-7	Al spherical shell, 10" diameter	8	22	60
RED-8	Fe sphere	8	27	55
YEL-1	Nylon disk with embedded Cu	12.5	1	2
YEL-2	Teflon disk with embedded SS	12.5	4	2
YEL-3	Teflon disk, 18cm diameter	12.5	7	10
YEL-4	Nylon disk, 10cm diameter	12.5	10	10
YEL-5	Al plate (white)	12.5	14	surface
YEL-6	Al plate (black)	12.5	17	surface
YEL-7	M-19	12.5	21	15
YEL-8	M-14	12.5	24	2
YEL-9	OZM-3	12.5	27	4
BLU-1	Fe Sphere	2.5	9	35
BLU-2	81 mm mortar	2.5	17	30
BLU-3	152 mm projectile	2.5	22	70
BLU-4	105 mm projectile	2.5	27	55

Location of Firing Point 22 Registration Targets

Target ID	Description	East (m)	North (m)	Depth to Top (cm)
REG-3-1	Fe sphere	105	60.5	5
REG-3-2	Al plate (4"x4"x0.5")	105	62.5	surface
REG-3-3	Al plate (8"x8"x1")	105	64.5	5
REG-4-1	Fe sphere	130	85.5	5
REG-4-2	Al plate (4"x4"x0.5")	130	87.5	surface
REG-4-3	Al plate (8"x8"x1")	130	89.5	5
REG-5-1	Fe sphere	140	10.5	5
REG-5-2	Al plate (4"x4"x0.5")	140	12.5	surface
REG-5-3	Al plate (8"x8"x1")	140	14.5	5

5.3.4 Side Bars

Target signature data will be collected in three Side Bars located adjacent to the Center Square, where background data will be collected. The contractors are expected to survey these areas as outlined in section 7. After all contractors complete their surveys and deliver the data to the government and some amount of data analysis has been done DARPA will release, to the contractors, a part of the ground truth from the Side Bars to permit internal system evaluation and performance measures.

The three Side Bars, labeled Blue, Yellow, and Orange have a total area equal to 1300 square meters. The total area containing targets is minimized so that within the time constraints of the test, each contractor can survey the appropriate UXO/mine signature targets twice and as much of the Center Square as possible.

5.4 Emplacement of Targets

All targets will be permanently marked with the target serial number prior to emplacement. The serial numbers are provided in Appendix D. During emplacement, the Target Emplacement Data Sheet, provided in Appendix A, will be completed for each target. The mine targets will be filled with explosive dielectric simulant prior to emplacement. The low-metal mines will also contain a small amount of metal surrogate. The location of the metal in the mine will be recorded on the Target Emplacement Data Sheet as described in Appendix A. The mine type, amount of metal surrogate, and explosive simulant to be used is provided in Appendix D.

All targets will be buried in such a way that only a minimum amount of soil and surface area are disturbed. Prior to digging, any sod or vegetation will be removed from the emplacement area and will be replaced after the target is buried. The emplacement hole will be located by survey and then excavated using either shovels or an earth auger (4-inch or 8-inch blade). The size of the hole will be slightly larger than the emplaced cross section of the target. If the hole dug is deeper than desired and needs to be backfilled prior to target emplacement the fill needs to be tamped to prevent sinking.

For emplacement of each target a series of photographs will be taken: (1) of the area before any disturbance, (2) the hole with the target placed next to it with the serial number of the target clearly visible, and (3) the surface after the emplacement is complete. To properly register the photographs taken, the target serial number, target ID, and site designator will be identified on a paper sign (provided on the back of the Target Emplacement Data Sheet) and included in each photograph taken. Using this method, identification information for each target will appear in each of the three photographs taken for each target emplacement.

The targets to be emplaced will be classified as either ferrous (UXO and iron spheres) or nonferrous (mines, nylon, aluminum, and Teflon). The ferrous targets will be demagnetized prior to placement in the hole. The demagnetization procedure is described in section 5.4.2. For those targets to be monitored by thermistors, the thermistor will be glued to the top of the target with the wires running up the wall of the hole and out to be connected with the wire bundle at a 90 degree angle as described in section 5.4.1. After placing the target in the bottom of the hole, the depth to the top of the item will be measured using a plumb line.

Mines, disks, spheres, and plates are placed lying flat in the bottom of the hole with the emplacement depth measured from the center using a plumb line to the surface. See Figure 5.7. UXO targets will be emplaced in one of three orientations: (1) vertical (inclination 90 degrees); (2) horizontal with the nose of the item pointing away from magnetic north (inclination of 0 degrees, declination of 0 degrees); and (3) horizontal with the nose of the item pointing perpendicular to magnetic north (inclination of 0 degrees, declination of 90 degrees). The declination of the ordnance item is measured relative to the geomagnetic declination.

Each of these orientations are illustrated in Figures 5.8 through 5.10. Using a plumb line, the depth of emplacement for UXO targets is measured to the top of the target (most shallow point).

The final surveyed target locations are measured from the center of the target with the target lying in the bottom of the hole. After surveying the target location, the hole is backfilled and tamped. For the targets instrumented with thermistors, two additional thermistors are to be emplaced as described in section 5.4.1.

5.4.1 Thermistor Emplacement

Thermistors will be deployed on some of the targets. (See Figure 5.11a.) Each monitored target will provide three readings: (1) the target temperature, (2) the soil temperature surrounding the target, and (3) the undisturbed earth in proximity to the target (of course some soil disturbance will occur while emplacing the thermistor).

For each buried target to be monitored, three thermistors will be deployed: (1) on the top of the buried target; (2) 2.54 cm (1 inch) below the surface and 2.54 - 5 cm (1-2 inches) away from the projected edge of the emplaced target; and (3) 2.54 cm

(1 inch) deep and 10 cm (4 inches) away from the disturbed earth surrounding the target. (See Figure 5.11b.) The wiring for each thermistor will be brought vertically to approximately 1 inch below the surface and connected at right angles to the wiring bundle that will lie in a straight line along the side of the Red Side Bar. (See Figure 5.11a.) The intent is to minimize the amount of wire in the calibration area and to clearly define the locations of all wires for later data analyses. The wire bundle will be placed inside a PVC pipe for protection and buried at a depth of 5 cm (2 inches). The wires leading up to the PVC bundle will be buried at a depth of 2.54 - 5 cm (1-2 inches).[2] Vehicle systems driving over the wires in muddy or wet conditions may cause the wires to break. If the connection to the thermistor is broken, the data will show a constant unrealistic temperature reading. The thermistor data will be downloaded and reviewed daily. On the days that the IR sensor is surveying, the thermistor data will be continuously monitored. If the data collected from the thermistors indicate a connection has been broken, the test director will have the connection to the thermistors repaired.

For the surface targets (YEL-5, YEL-6, and RED-3) the first thermistor will be placed between the target and the soil surface. The second thermistor will be 2.54 - 5 cm (1-2 inches) from the edge of the target, as it is for buried targets. The third thermistor will be buried 2.54 cm (1 inch deep) and 20 cm (8 inches) away from the target.

5.4.2 Demagnetization of Ferrous Targets

All ferrous targets should be subjected to a procedure that attempts to reduce the remanent magnetization to a level that is smaller than the expected geomagnetically induced signature. The demagnetization or degaussing procedure is carried out on site just prior to emplacement. The demagnetization is accomplished by a mechanical shock to the ferrous object.

The mechanical shock to the ferrous target is achieved by four or five hard strikes with a small sledge hammer. The mechanical shock will cause the total magnetization of the ferrous object to relax towards the magnetization level induced by the geomagnetic field. Once this has been completed, if available, a full field gradiometer is used to measure the signature of the emplaced target. If the target signature does not fall close to the expected signature range, the ferrous target is again struck with the sledge hammer four or five times. If after this, the signature is not close to the expected signature, the item is emplaced, and the discrepancy is noted in the comment section of the Target Emplacement Data Sheet. If a magnetometer is not available after the initial mechanical shocks, the target will be emplaced.

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[2] The wire bundles on the Fort A.P. Hill sites were not buried nor were they placed in PVC pipes. The wires were protected from the vehicles on the southern edge of the site by a wooden support structure.

5.4.3 Survey of Target Locations

Target locations will be surveyed using a total station survey instrument with millimeter accuracy. These locations will be measured in a local coordinate system, mapped in AutoCAD, and provided in an ASCII file.

The calibration targets will be marked on the surface with colored paint and the target number will be clearly identified. The registration targets will also be marked with paint and flags so the locations of those targets will be clearly visible.

6. Test Execution

The following test schedule was coordinated with WES, NVESD, Institute for Defense Analyses (IDA), DARPA, and the contractors. The Site preparation, which includes background characterization and emplacement and survey of targets, will be completed by September 9 at Fort A.P. Hill and by September 13 at Fort Carson. The contractor test schedule at each site is as follows:

Week	Fort A.P. Hill, Virginia	Fort Carson, Colorado
Sept. 11-13		
Sept. 16-20	SAIC (EM,IR)	
Sept. 23-27		GeoCenters (GPR,IR)
Sept. 30-Oct. 4	Parsons (M, EM)	GeoCenters (GPR,IR)
Oct. 7-11	Geometrics (M)	SAIC (EM,IR)
Oct. 14-18		LLNL (GPR)
Oct. 21-25	GeoCenters (GPR,IR)	Parsons (M,EM)
Oct. 28-Nov. 1	GeoCenters (GPR,IR)	Geophex (M,EM)
Nov. 4-8	Coleman (GPR, EM)	Geometrics (M)
Nov. 11-15	Geophex (M,EM)	Coleman (GPR, EM)
Nov. 18-22	LLNL (GPR)	

A weekly schedule will be maintained at each site for each contractor. The planned schedule is shown below; adjustments to this schedule can be made on site in the event of inclement weather or contractor equipment failures. The rough daily schedule included here is intended to give test personnel and the contractors a quick way of gauging the test progress while on site. An 8 hour day is assumed in this schedule, it is recommended that when the weather is good the days be longer.

Sunday

Travel and preliminary system setup

Monday

Contractor system setup (2 hours)
Calibration (2 hours)
Begin first pass of first site (4 hours)

Tuesday

Complete the first pass of the first site (8 hours)

Wednesday

Perform second pass of the first site Side Bars (2 hours)
Transfer to the second site (1 hour)
Calibration at second site (2 hours)
Begin first pass of second site (3 hours)

Thursday

Complete the first pass of the second site (6 hours)
Perform second pass of the second site Side Bars (2 hours)

Friday

This time is reserved for (1) slippage in the schedule during the first 4 days, (2) continuing to survey the portion of the Center Square not surveyed, or (3) performing repeat passes of the Side Bars areas of one or both sites.
Pack up system (2 hours)

Saturday

Travel

6.1 Test Logistics

The contractor is responsible for shipping equipment to and from the test locations. The government will provide shelter for the systems during the duration of the test. Several areas at the Fort A.P. Hill site become covered with standing water after rain and may take several days to dry. Therefore, it is strongly recommended that surveys be conducted aggressively when the site conditions are favorable. The amount of time for surveying will be restricted only by the daylight hours available. Work can not be conducted on the weekends at Fort A.P. Hill, however, weekend work at Fort Carson might be an option.

6.1.1 Logistics at Fort A.P. Hill

Fort A.P. Hill can be reached by flying into one of three major metropolitan area airports: Washington National, Washington Dulles, or Baltimore Washington International (BWI) or the Richmond airport. The closest hotels are located in Fredericksburg, Virginia, approximately 2 hours drive from both Washington National or Richmond and 3 hours drive from BWI. A list of hotels is provided in Appendix C.

Packages can be shipped to the FEDEX Station:

FEDEX(STATION)
1117 International Parkway
Fredericksburg, VA 22401

Hours: M-F 8:30 a.m. - 7:00 p.m.

Sat. 8:30 a.m. - 5:00 p.m.

Hold for counter pickup is available after 9:30 a.m. on the day delivered. The FEDEX station is located off Exit 133 (left towards Warrenton) in the Stafford Industrial Park, across the Highway from the GEICO insurance building.

Prior to arrival on site, the single point of contact for questions regarding logistics at the Fort A.P. Hill site is Roshni Mehta (703) 704-2477. Once at the site the point of contact is Ed Nawrocki. A hanger at the 71A site at Fort A.P. Hill has power and will be available for system storage during the duration of the test. Access to the hanger is limited by the range control personnel (804) 578-8785. Security for the system is maintained by limiting access to the 71A site. A small trailer is also located at 71A, which contains a facsimile machine, a telephone and desk, (804) 633-8789 (phone) or (804) 633-8275 (answering machine).

Directions to Fort A.P. Hill from Virginia are as follows: take route 95 south to the Massoponax exit No. 126. Turn right at the end of the exit ramp (Rt. 1 south). Pass the McDonald's on the left, then turn left onto Rt. 17 (east). Follow for 6 or 7 miles, and then turn right at the flashing yellow light (Rt. 2 south). Follow Rt. 2 south for 10 or 12 miles. Turn left at Bowling Green (Rt. 106 to Rt. 301). Turn left at the divided highway (Rt 301). Turn right at the Fort A.P. Hill entrance. Range control is the first set of buildings on the left. The trip takes 1 hour and 30 minutes to travel from Washington D.C. to exit No. 126. Then from there to the Massoponax exit is another 30 minutes. A map and directions can be found in Appendix C.

Directions to Fort A.P. Hill from Maryland are as follows: take Rt. 210 south to Rt. 228 and turn left. When you get to route 301 turn right; follow 301 south to Fort A.P. Hill. There is a toll bridge on that collects $1.50 per car traveling from Maryland to Virginia; toll is not collected on the return trip. Entrance to Fort A.P. Hill on the left. See map in Appendix C.

On the Monday of each contractor's week of testing, the contractor must be at range control at 0700. Range control will perform check in and transport the contractor to one of the two sites, either Firing Point 20 or Firing Point 22. The contractors are advised to bring water and lunch, there are no eating facilities near either site or 71A. It is recommended that you bring plenty of clothes and rain gear since the weather in the fall can be unpredictable.

6.1.2 Logistics at Fort Carson

Fort Carson can be reached by flying into Colorado Springs. A list of hotels is provided in Appendix C. The Red Lion, Hampton, or the Sheraton Colorado Springs hotels are recommended. Please make reservations as soon as possible. Prior to arrival on site the single point of contact for questions regarding logistics at the Fort Carson site is Jose Llopis (601) 634-3164. Once at the site the point of

contact is Tommy Berry (601) 634-3927. A point of contact at Fort Carson is Gary Belew, Chief of the Natural Resources Division, (719) 526-1694, fax: 1705.

For pre-arrival shipping of materials to Fort Carson, use the following addresses:

HQ Fort Carson
AFCZ-ECM, Bldg. 322 (Gene Blake)
Fort Carson, CO 80913-5000
Phone: (719)526-3975

Large packages and equipment should be shipped to the FEDEX Station for pickup at:

FEDEX (STATION)
5010 Centennial Blvd.
Colorado Springs, CO 80919

Operating hours are Monday through Friday, 8:30 a.m. to 7:30 p.m., and Saturday 9:00 a.m. to 5:00 p.m.

Directions to Range Control are as follows. Take Rt. 115 south towards Pueblo. Turn left on the first road after gate 5. There is a large prehistoric rendition of a bug on the right hand side. Follow this road to just prior to the first stop sign. The building on the left is range control. You must stop at range control to get a visitors pass. The Test Director will take you to the Seabee and Turkey Creek sites from there.

No facilities for equipment storage are available at the test sites. Storage will be available at Fort Carson; building numbers will be provided. Because there are no access restrictions at the Fort Carson site, the sites themselves are unsecured; all contractors may come and go unescorted.

At 0600 on the Monday of each contractor's week of testing the contractor must meet at a to be determined hotel and participants will be convoyed to Range Control from there. A supply of several changes of warm clothing and rain gear is recommended because the weather in the fall can be unpredictable. Bring water and lunch because there are no eating facilities near either site.

7. Survey Procedure

This experiment is designed to support a primary purpose of obtaining calibrated and registered clutter data. Signature data for ordnance items and mines will be collected to the greatest extent possible, while maintaining the desired clutter data collection. A detailed layout of the sites is described in section 5. The site is divided into areas for three primary purposes: Calibration for sensor calibration; Side Bars, for target signature data collection; and a Center Square, for collecting background clutter data, see Figure 5.2a.

Three Side Bars are designated Yellow, Blue and Orange, and they will contain mine and UXO targets as described in section 5. These Side Bars will be surveyed by the various sensors as outlined below to provide target signatures. The calibration area is 30 m x 15 m. It includes a portion of the Blue and Yellow Side Bars as well as a Red lane. The main data collection area, designated as the Center Square, is a 100-m x 100-m area where background clutter data will be collected.

If weather or environmental conditions require that a sensor settings need readjustment, then the operator will need to go back to the calibration area, and attempt to detect the system stressing target and the registration targets to reset (and record) the system settings.

7.1 Calibration

Prior to beginning data collection, the contractors will be permitted up to 2 hours in the calibration area to adjust their systems. *All system settings must be recorded after the system is calibrated. Additionally, these system settings are to be maintained throughout the site survey. If the system settings are changed, they must be recorded and the contractor must visit the calibration area and record target signatures again.* The Yellow and Blue areas that extend into the calibration area will also be surveyed as outlined in the next section to obtain target signature data deliverable to the government. Specific information about the location, target type, and depth of the calibration targets is provided in section 5.

7.2 Surveys of the Side Bars and Center Square

After the contractors have finished tuning their sensors in the calibration area, they will be required to survey the appropriate system stressing target(s). Contractors must show the test director that the system is detecting the designated system stressing target. Sensors that fail to detect the stressing target will continue making adjustments in the calibration area until the sensor responds to the stressing target or until it is determined by the government that continued adjustment will not result in the required sensitivity. If, after repeated attempts, a sensor fails to respond to the stressing target, the operator will proceed to survey the targets in the calibration lane that mimic the registration targets on the main clutter site. All sensors must detect the registration targets in the calibration lane before they will be permitted to begin the data collection. If, after an interval deemed reasonable by the government, the sensor does not record a response to the registration targets, the contractor may be asked at government discretion to cease work on the site.

Data will be collected on the Side Bars, the Calibration Area, and the Center Square with all adjustable sensor settings identical to those used to pass the "go" test. Sensor settings will be recorded and provided to the government. These sensor settings are to be stored in the BSF header in the data provided by the contractor. All target areas are to be surveyed at the same resolution and system settings that will be used on the Center Square. See Appendix B.

In section 5.3, contractors are provided a list of all system stressing targets and registration targets. If any contractor determines in advance of arrival on the site that his sensor will be unable to detect these targets, he/she must provide to the government as soon as possible the identification of the targets that will not be observable, experimental data or calculations indicating why the target(s) will not be observed, and an assessment of the minimum signature necessary for reliable detection and registration.

Data collection will begin with one pass on the Side Bars. Because not all sensors are designed to detect all of the different targets emplaced, not all contractors will be required to survey all of the Side Bars and calibration targets; only those that are relevant will be surveyed. In addition to the Red lane in the calibration region, the required surveys are listed in the table below as a function of the sensor type. The Blue and Yellow requirements indicate that both the Calibration and Side Bar of that color are to be surveyed. This survey will be continuous through the Calibration and Side Bar areas.

Sensor	**Target Areas To Be Surveyed**	**Target Area Required (m2)**	**Clutter Area Required (m^2)**	**Survey End Line**
Mag	blue, orange	2,000	8,000	95 m, Yellow
GPR high	blue, yellow	1,600*	8,400	100 m, Orange
GPR low	blue, yellow, orange	2,600	7,400	90 m, Blue
EMI	blue, yellow, orange	2,600	7,400	90 m, Blue
IR	blue, yellow	1,600	8,400	100 m, Orange

* The areas to be surveyed by the IR sensor are the same as those to be surveyed by the high frequency GPR because the IR sensor will be carried on the same platform as a high frequency GPR sensor (GeoCenters).

Following one survey of the required target areas, contractors will proceed to the Center Square. After finishing the Center Square, the contractors will then survey the required target areas again, with the direction of travel reversed from the first pass. Because the contractors agreed to survey a total of 1 hectare (10,000 m^2) at each site, the survey area required of the contractors in the Calibration and Side Bars will be subtracted from the area of the Center Square required. See Figure 5.2a. Contractors will be allowed to stop at survey end lines (marked in Figure 5.2a as colored dashed lines), depending on the area required in the Calibration and Side Bars. The total area required of each contractor at each site for each location will be 10,000 m^2.

All contractors will begin the survey of the Center Square in the same location. They will proceed heading north and stop at the flag with the appropriate distance annotation. All registration targets will be placed so that they are contained in the smallest portion of the Center Square that any contractor is required to survey. The contractors will survey with their direction of travel as near as possible to north/south in the geomagnetic reference frame.

Should any time remain after the required 10,000 square meters have been surveyed, the contractors will survey the remaining part of the clutter area and then proceed with another pass over the appointed target areas.

In summary the site survey will proceed as follows:

1. Calibration area
2. First Pass Side Bars
3. Center Square to designated end flag
4. Second Pass Side Bars
5. Remaining area in the Center Square
6. Third Pass Side Bars
7. Center Square to designated end flag

Each contractor will submit the data to DARPA—in the BSF format specified in Appendix B—no later than 2 weeks after conducting the survey.

7.3 Procedures Unique to Sensor Type

The infrared (IR) sensor system requires calibration and registration targets on the surface. These surface targets will be located at the 5 registration points in the Center Square and 2 locations in the calibration area. The surface IR targets will be temporarily removed from their location just prior to survey by the induction coil sensor. Test personnel will then replace the IR target after the induction coil has passed by. The operator of the induction coil/IR system needs to coordinate actions with test personnel to assure that the induction coil does not pass over an IR surface target.

7.4 Local Survey Procedure (LLNL)

The purpose of the LLNL GPR sensor is to provide unique GPR data on selected areas of the site. It was our intent to structure the test schedule so that all of the GPR sensors would survey a site prior to the LLNL survey. Then while the electromagnetic induction, magnetometer and infrared sensor systems surveyed the site we could review the GPR data collected and identify site areas of interest. The LLNL sensor would then survey the prioritized list of interesting areas until time available was exhausted. The current schedule reflects constraints other than the scientific considerations listed above. Additional details on the testing procedure for LLNL will be provided at a later date.

7.5 Test Personnel and Duties

During each test, personnel from WES and NVESD will be present on site and will be designated the test director. In addition, one person from either IDA, Walcoff, or DARPA will also be present and will be designated the test consultant. The duties of the test director, who is responsible for the execution of the data collection program, include the following:

- Providing for equipment storage and retrieval needs of the contractors.

- Insuring that a test consultant is present on the site during site surveys.
- Coordinating actions with the appropriate range personnel.
- Maintaining the test schedule.
- Seeking the advice of the test consultant before making any changes to the site, the schedule, or the procedures.
- Serving as a single point of contact for the contractors.
- Providing a debriefing to DARPA at the end of each day.
- Moving and replacing IR targets.
- Monitoring the detection of system stressing targets.
- Recording the contractor system settings prior to site survey and recording any necessary changes to those settings as the survey proceeds.
- Providing a supply of forms, pens, and pencils for data logging.
- Providing radios for communications.
- Performing other duties as appropriate.

The duties of the test consultant include the following:

- Maintaining a daily log of the test, using forms provided in Appendix A.
- Providing technical guidance to the test director.
- Providing a debriefing to DARPA at the end of each day.
- Taking photographs of the participating systems.
- Performing other duties as appropriate.

A representative from WES will be at the site at all times monitoring the weather stations and other equipment collecting data. WES is responsible for ensuring that the appropriate weather station and navigation data is collected on site at all times.

8. Data Analysis and Products

This section attempts to identify tasks that will be performed using the collected data. It is critical that decisions be made in advance of data collection to ensure that the data collected will meet the needs of those tasks. Of course, it is impossible to determine a priori exactly what processing will be done on the data but some rudimentary data processing techniques will certainly be performed. Both IDA and the Applied & Computational Mathematics Program at DARPA will perform a detailed analysis of the data collected, and they will use two very different techniques. A subset of the data collected at the site will be provided to both entities for their analysis. DARPA intends to retain the remaining data to test the results of the analyses. In addition, data will be made available, with minimal restrictions, for other data analyses. The proposed analyses efforts of IDA and DARPA are described briefly below.

8.1 IDA Analysis

The first step is to characterize the single-point statistics. The single-point statistics need to be generated for the entire data set collected and on each hectare. Changes in the distributions from hectare to hectare need to be quantified and explained. These single-point statistics do not take into account any spatial information in the images

provided; use of that information is described in the second step. To characterize single-point statistics, do the following:

a) Create a distribution of the single pixel values to determine whether the distribution is single- or multi-moded.

b) If single-moded, determine the best overall distribution that describes the data (Gaussian, Lorentzian, Weibull, etc.). If multi-moded, determine best multi-moded approach.

c) If the usual sensor discrimination algorithm is a threshold, then apply a reasonable threshold on the data to approximate a false alarm rate and a probability of detection. That is, assume a minimum target signature value. Assume pixel values below this threshold can never be a targets (be conservative and use multiple values). Clutter pixel values above the chosen threshold will compete with possible targets. This method of thresholding can be illustrated as shown in Figure 8.1.

d) The majority of the distribution will have Z values less than the threshold and will not be confused as targets. Characterizing the clutter distribution as 99 percent *something*, e.g., Gaussian, is useful for comparing sensor performance, because the tail of the distribution is the most important for mitigating false alarms. It may be that the 1 percent of the distribution that is not *something*, e.g., Gaussian, contains 100 percent of the pixels that are confused as targets. From this point on, the emphasis will be placed on characterizing the tail of the clutter distribution.

e) Use distribution tests, e.g., Kolmogorov-Smirnov, to compare the similarity of two distributions for the whole distribution and the tails. Find the distribution that best describes the data.

f) Identify outliers on single-point distributions. They are, by definition, rare. Do isolated pixels or groups of pixels with unusually high values seem to deviate from a smooth fit to the tail? See Figure 8.2. Are these pixels obviously associated with objects or features at the site, such as a diamond ring, a horse shoe, a nugget of iron, etc.? What if an outlier does not reveal any identifiable feature? Check to see if the pixel is also identified by other sensors; in other words, is it consistent? Do an engineering failure analysis; can it be attributed to a noise spike in the sensor? Are there more than one like this, one that cannot be assigned to a particular feature? If there is more than one, do a statistical analysis.

g) Produce a taxonomy of outliers (a diamond ring, a horse shoe, a nugget of iron, etc.). Discrete outliers cannot be considered statistically from a single site—for instance, if a campfire is a source of threshold exceedance. Even if there is only one such fire in the measured site, this is important because there may be many more campfires at some other site. Furthermore, knowing that campfires are a problem allows one to design an algorithm to eliminate campfires. But a "campfire

eliminator" may also eliminate some targets. Targets that are eliminated using a single sensor algorithm may be restored by using an algorithm that will overlay images of the site from multiple sensors, to design a "campfire eliminator" that does not eliminate desired targets. Beware, if campfires reside in the portion of targets that are below the threshold; this may indicate that "campfire" is not a reliable description of the false alarm source.

The second step is to characterize the multi-point distributions, which take into account the spatial or 2-D information provided in the image. To characterize multi-point distributions, do the following:

a) Start with a 2-point correlation or equivalently the power spectral density (PSD).[3] The PSD provides a coarse level description of the spatial information in the scene. For example, the PSD of a checkerboard shows a strong peak at the spatial frequency of the board, while a white noise image of uncorrelated pixels has a flat constant PSD.

b) Look for symmetries in the 2-D of the PSD. Is the scene isotropic? If there are preferred directions exist, are they correlated with natural features such as cultivation history, streams, gradients in terrain? Aerial photographs and geological descriptions of areas 10 to 12 feet below ground level are appropriate aids. Also check that the image is rotationally symmetric. If it is not, find out why.

c) PSD distributions seldom correctly describe clutter statistics at low false alarm rates. They correspond spatially to the below-threshold portions of the single pixel distribution. See Figure 8.1. To determine if the PSD is an accurate model of the spatial distribution, predict threshold exceedances versus threshold using the PSD description (depending on algorithm, this may or may not be a matched filter prediction) and compare with reality. In other words, predict performance as a function of threshold. One way to do this, independent of an algorithm, is to use the PSD to synthetically make a scene with the same first- and second-order statistics and compare exceedances on a real versus a simulated scene.

d) Look for outliers in correlation space, which are clutter discretes not captured by a PSD description. For example, a scene with a random arrangement of mole hills occupying 99 percent of the scene will be dominated by those mole hills. Produce a taxonomy of such nonrandom items, such as streams, fence posts, underground formations, cultivation boundaries, etc.

e) Calculate the PSD of just the threshold exceedances (the tail of single pixel distribution), and characterize. Produce maps of false exceedances and hypothesize relation to gross site characterization. Are threshold exceedances caused by identifiable discretes, e.g., along stream beds?

[3] The power spectral density is the magnitude squared of the Fourier transform of the image.

f) Determine how taxonomies of outliers in single-point statistics and multi-point statistics compare as a function of technology. Is there an obvious, or not so obvious, way to exploit this without sacrificing ordnance detections?

In essence, after completing the above steps a model or representation of the background could be developed; this model could then be used to create synthetic background scenes and compared with real images in exceedances versus threshold. For example, a scene representation might include an underlying PSD description with discretes added in an appropriate fashion to simulate the expected background. If a model can be developed, these synthetic scenes can be used to increase the amount of background images available for sensor development and performance measurement.

For different sites, repeat all of the above and do cross-comparisons, as follows:

a) For example, first order distributions may or may not be Gaussian or anything specific. Use distribution-similarity tests, e.g., Kolomorgorov-Smirnoff, on the whole distribution and on the tails to check for similarity between sites.

b) Do the same for discretes, second order statistics, and so forth.

After this analysis has been completed it is expected that the following will have been learned:

a) The establishment of baseline first- and second-order statistics—no algorithm can work if these statistics are not known. First-order statistics give thresholds or contrast values. Second-order statistics determine possibilities of matched filters for spatially resolved targets. First- and second-order statistics are necessary, but are not sufficient, to reduce the false alarm rate. First- and second-order statistics describe the target and clutter in a large-scale sense and allow for an estimate of expected P_D, given a simple thresholding algorithm. Because false alarms are a result of the discrete sources in the tail of the distribution, false alarm mitigation will probably require understanding the characteristics of these discrete sources.

b) The identity of false alarm sources—it is not possible to design a sensor/algorithm for eliminating false alarms until the features of the false alarms have been defined.

c) How to ameliorate false alarms—For example, if a clutter discrete such as a fence line is a problem, the above analysis will help devise specialized algorithms to winnow it out. Of course, winnowing out the fence line also winnows out detections of ordnance located under the fence line. One can also quantify any similarities between individual clutter images and individual target images. Can any individual differences be exploited? A substantial amount of image processing and image understanding work from many diverse communities can be leveraged.

d) How to build a model for the expected background—This model can then be tested in subsequent data trials to determine if it is a fragile, brittle, useless model or if it will help assess technologies, sensors, and algorithms.

8.2 DARPA's Applied and Computational Mathematics Program Analysis

The Applied and Computational Mathematics Program (ACMP) at DARPA headed by Dr. Anna Tsao has suggested that the data collected might be suitable for processing using wavelet analysis. This technique concentrates on extracting features that are unique to targets, thus serving as discriminants from features characteristic of clutter. This technique was used successfully on the Longbow data as well as several other diverse data sets for both military and medical applications. However, the number of targets emplaced for this data collection may prove to be too few for this mathematical technique to be successful. It is for this reason that multiple passes of the SIDE BARS have been included in the test plan. Multiple passes over the same emplaced targets may provide enough target data to help extract those features unique to UXO.

A description of analysis to be performed by DARPA's ACMP will be provided at a later date.

8.3 Data Analysis by Others

Data analysis by other entities is encouraged. The various contractors whose sensors were used to collect the data have requested that information gleaned from the data particular to their sensor be shared with them. In keeping with the cooperative nature of this program, DARPA would not approve of any effort to use the data collected for the sole purpose of criticizing the performance of any of the sensors used for the data collection.

9. References

Altshuler, Tom. 1996. "Shape and Orientation Effects on Magnetic Signature Prediction for Unexploded Ordnance," UXO Forum 1996, March 26-28, 1996 (pp. 282-291), Williamsburg, Virginia.

Barrow, Bruce, et. al. 1996. "Performance of Electromagnetic Induction Sensors for Detecting and Characterizing UXO," UXO Forum 1996, March 26-28, 1996 (pp. 308-314), Williamsburg, Virginia.

Butler, Dwain K., Wahl, Ronald E., Mitchell, Nolan W.R., and Hempen, Gregory L. 1988. "A Survey of Engineering Geophysics Capability and Practice in the Corps of Engineers," Technical Report REMR-GT-9, U.S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi.

Butler, Dwain K. 1994a. "Detection and Delineation of Subsurface Cavities, Tunnels and Mines," Proceedingsof the 1994 Geotechnical Lecture Series, Illinois Section of the American Society of Civil Engineers, Chicago.

Butler, Dwain K. 1994b. "Environmental Geophysics: The Best Kept Secret of Environmental Cleanup," Proceedings of the 1994 Geotechnical Lecture Series, Illinois Section of the American Society of Civil Engineers, Chicago.

Butler, Dwain K., Simms, Janet E., and Cook, Daryl S. 1994. "Archaeological Geophysics Investigation of the Wright Brothers 1910 Hangar Site: Wright-Patterson Air Force Base, Ohio," Technical Report GL-94-13, U. S. Army Engineer WES, Vicksburg, Mississippi.

Butler, Dwain K., Sharp, Michael K., Sjostrom, Keith J., Simms, Janet E., Llopis, Jose L., Fitterman, David V. 1996. "Assessment of Geophysical methods for Subsurface Geologic Mapping, Edgewood Area, Aberdeen Proving Ground," Technical Report GL-96-20, U.S. Army Engineer WES, Vicksburg, Mississippi.

Corps of Engineers. 1963. "The Unified Soil Classification System," Technical Memorandum 3-357, U.S. Army Engineer WES, Vicksburg, Mississippi.

Corps of Engineers. 1979, 1995. "Geophysical Exploration," Engineer Manual EM 1110-1-1802 (revision 1995), U.S. Army Engineer WES, Vicksburg, Mississippi.

Curtis, John O., Weiss, Charles A., and Everett, Joel B. 1995. "Effect of Soil composition on Complex Dielectric Properties," Technical Report EL-95-34, U.S. Army Engineer WES, Vicksburg, Mississippi.

George, Vivian, Andrews, Anne, et. al. 1996. "A Background Characterization Experiment to Advance the State of the Art in UXO and Landmine Detection", IDA, to be published.

Means, R.E., and Parcher, J.V. 1963. Physical Properties of Soils, Charles E. Merrill Publishing Company, Columbus, Ohio.

Simms, J.E., and Butler, Dwain K. 1995. "Full Waveform Inverse modeling of Ground Penetrating Radar Data: An Initial Approach," Miscellaneous Paper GL-95-4, U.S. Army Engineer WES, Vicksburg, Mississippi.

Telford, W.M., Geldart, L.P., and Sheriff, R.E. 1990. Applied Geophysics, Cambridge University Press, New York.

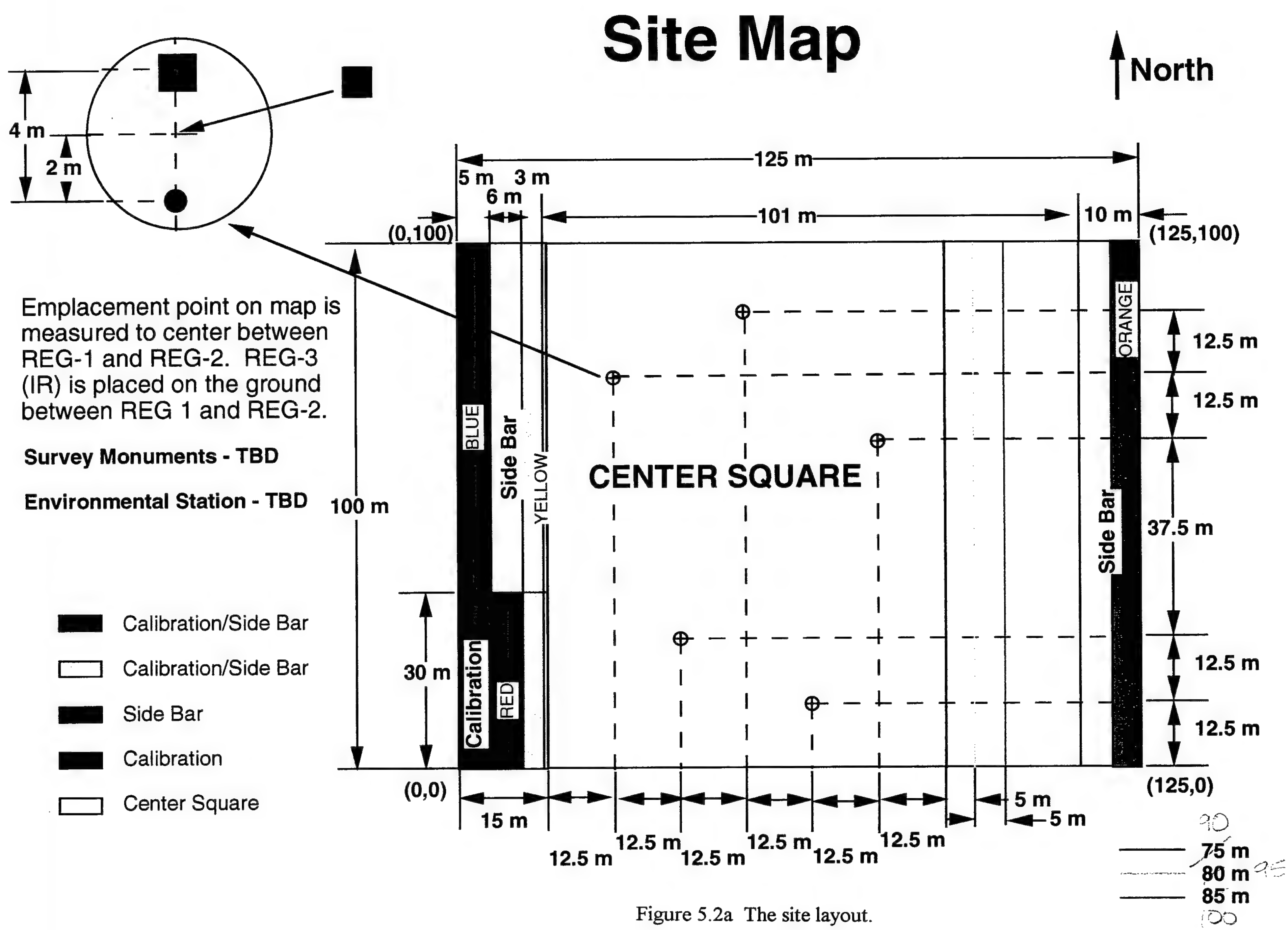


Figure 5.2a The site layout.

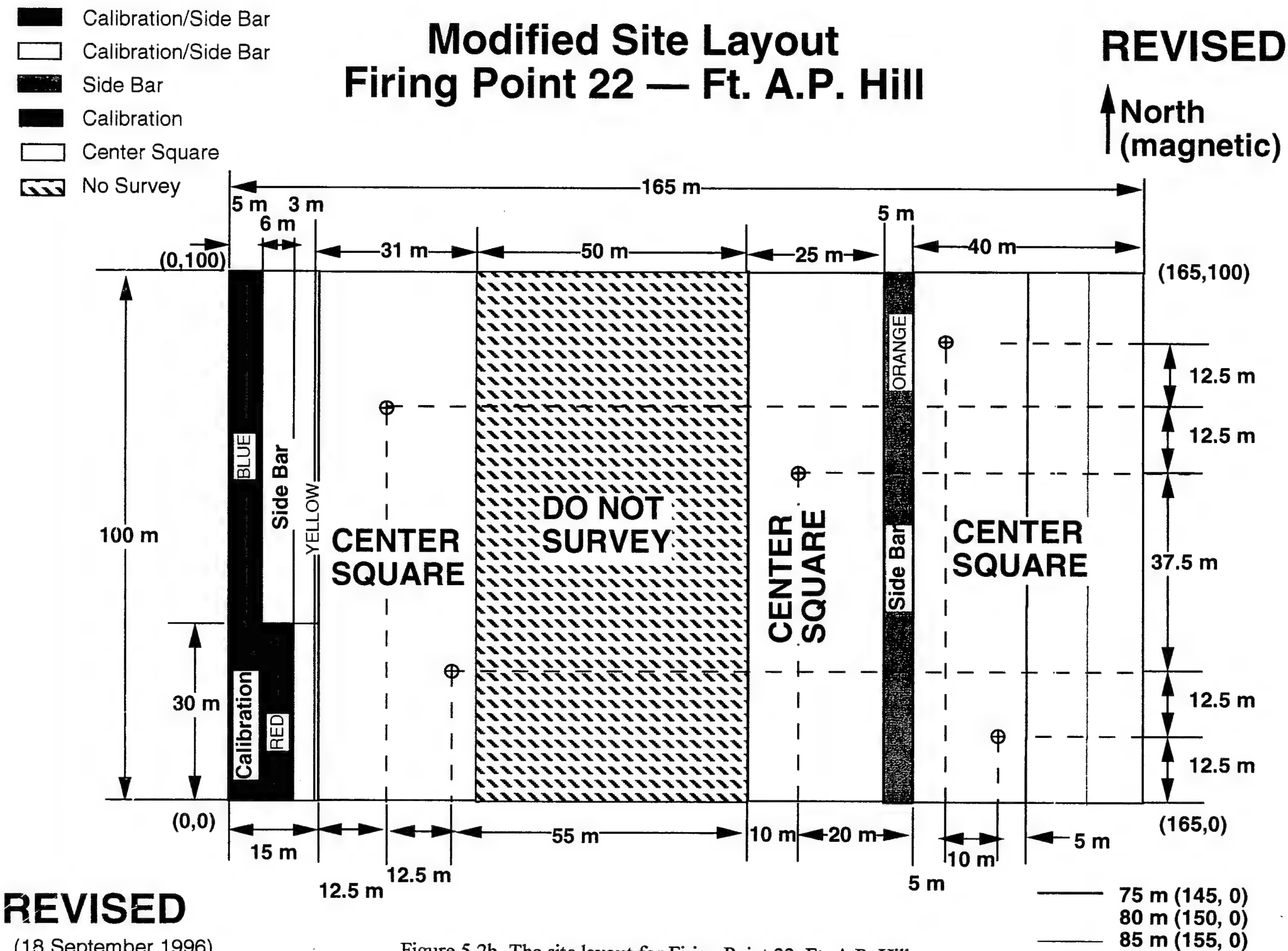


Figure 5.2b The site layout for Firing Point 22, Ft. A.P. Hill.

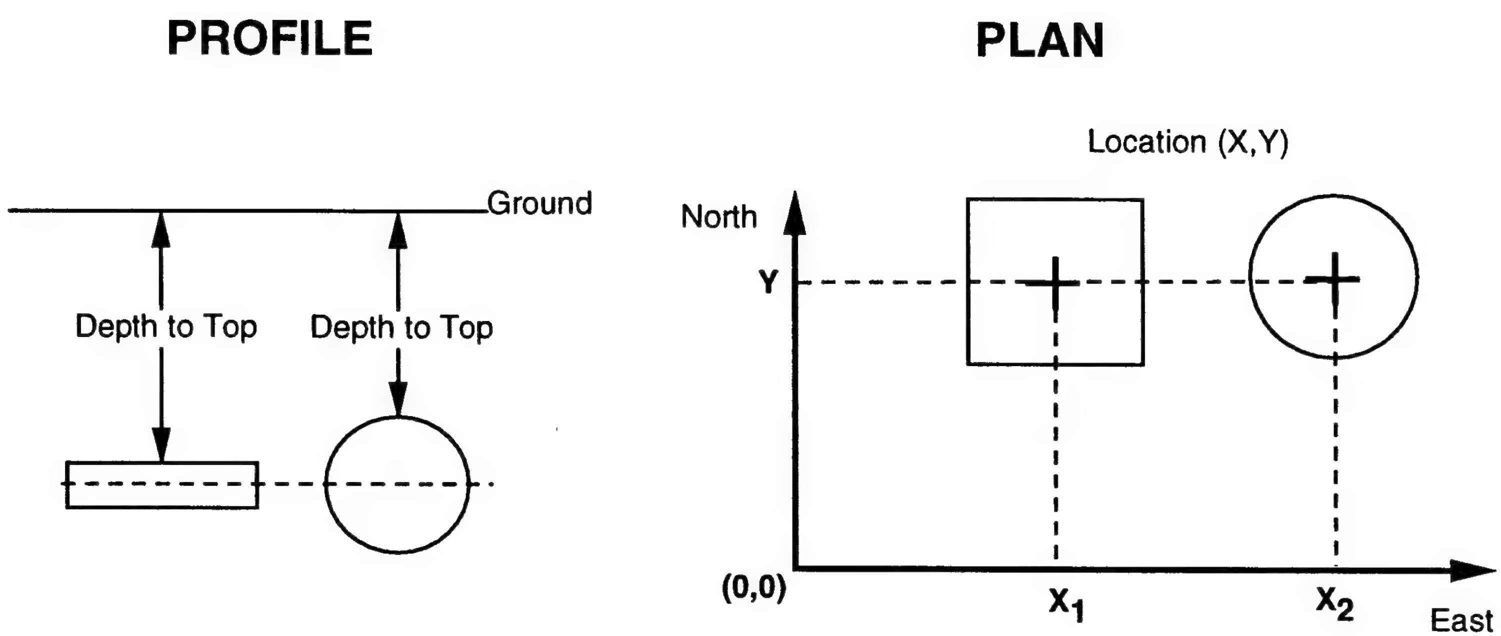


Figure 5.7 Emplacement of targets.

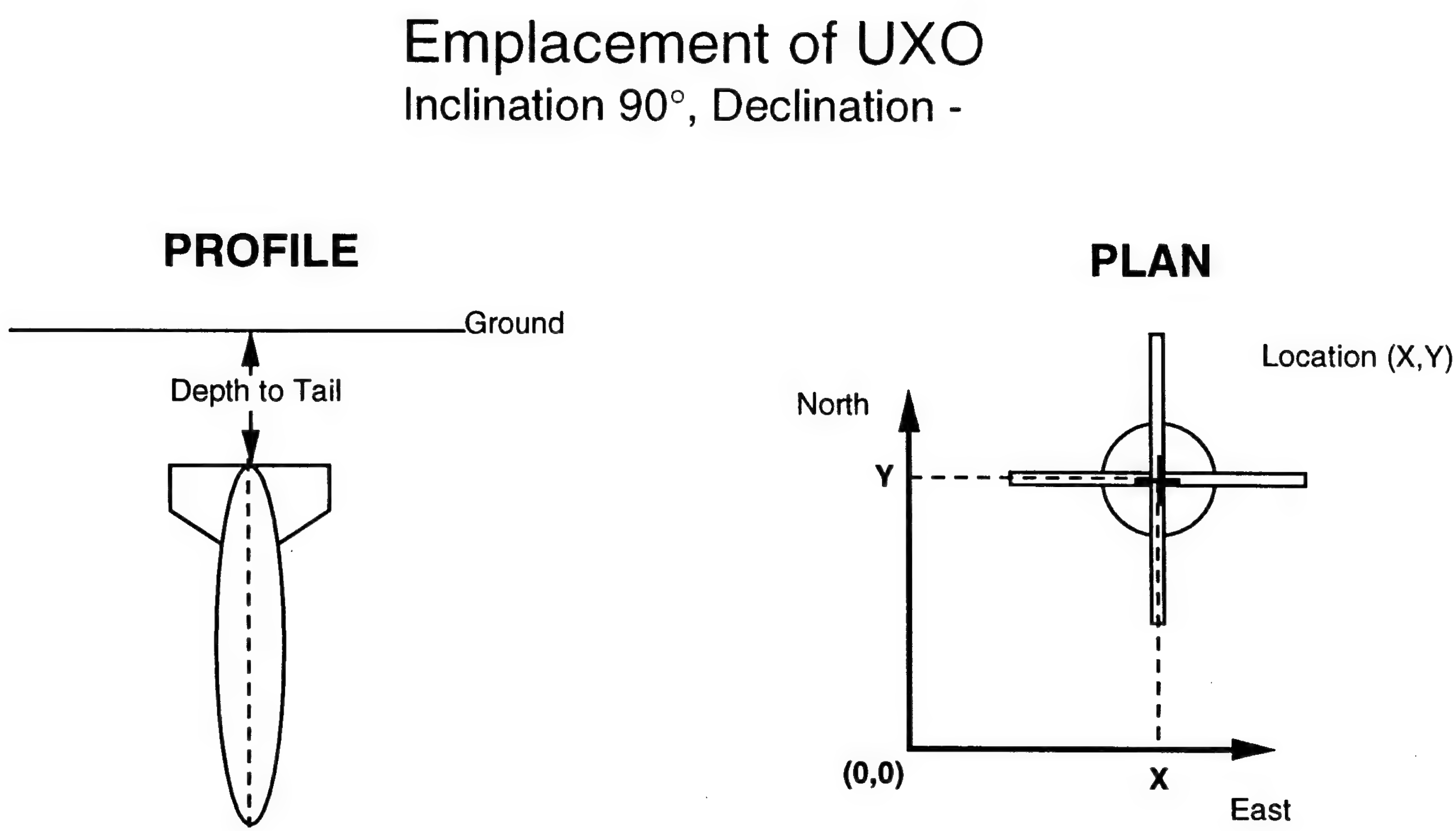
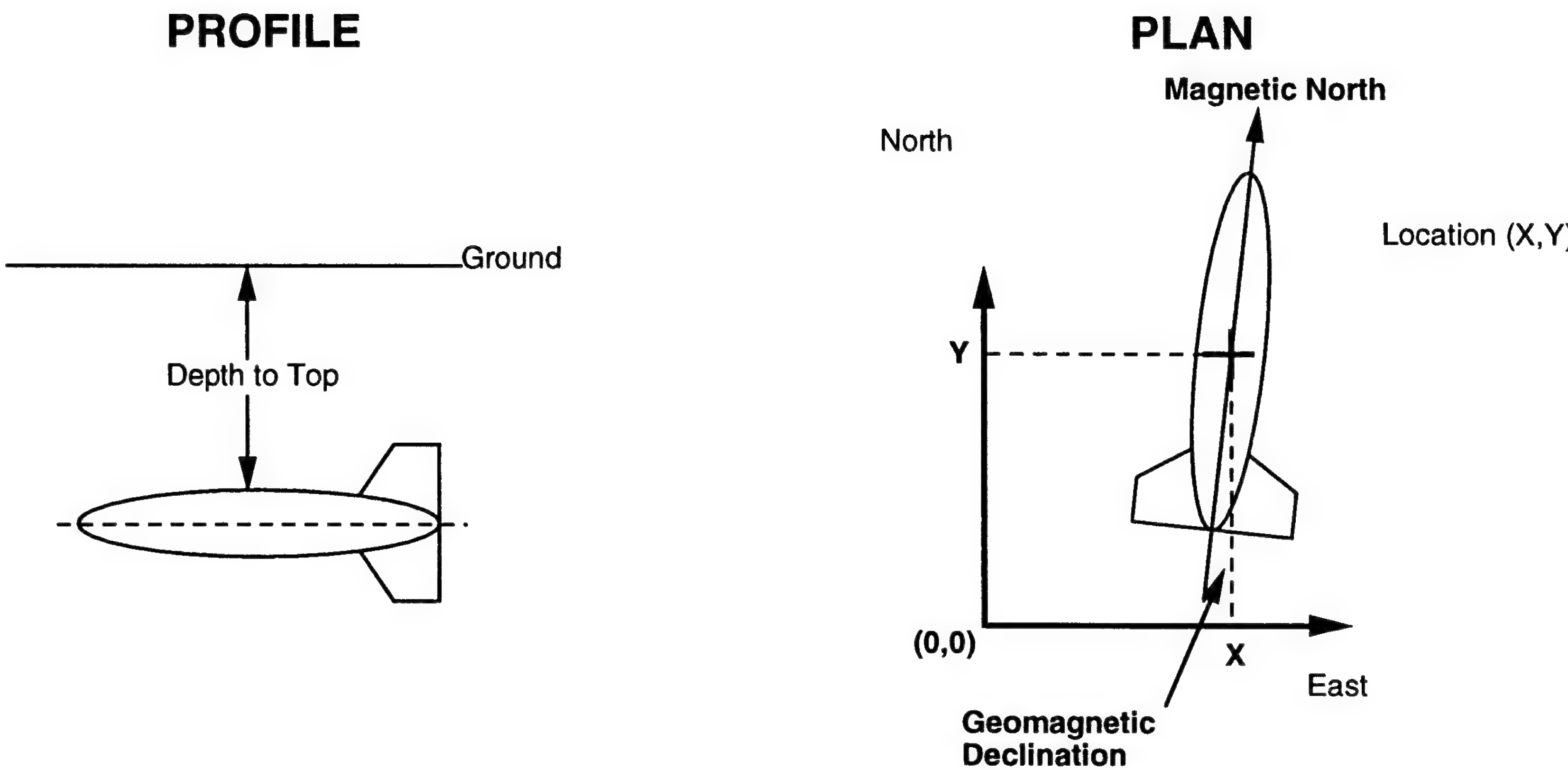


Figure 5.8 Emplacement of UXO, Inclination 90°, Declination –



a. The declination is measured relative to the geomagnetic declination

Figure 5.9 Emplacement of UXO, Inclination 0°, Declination 0°.

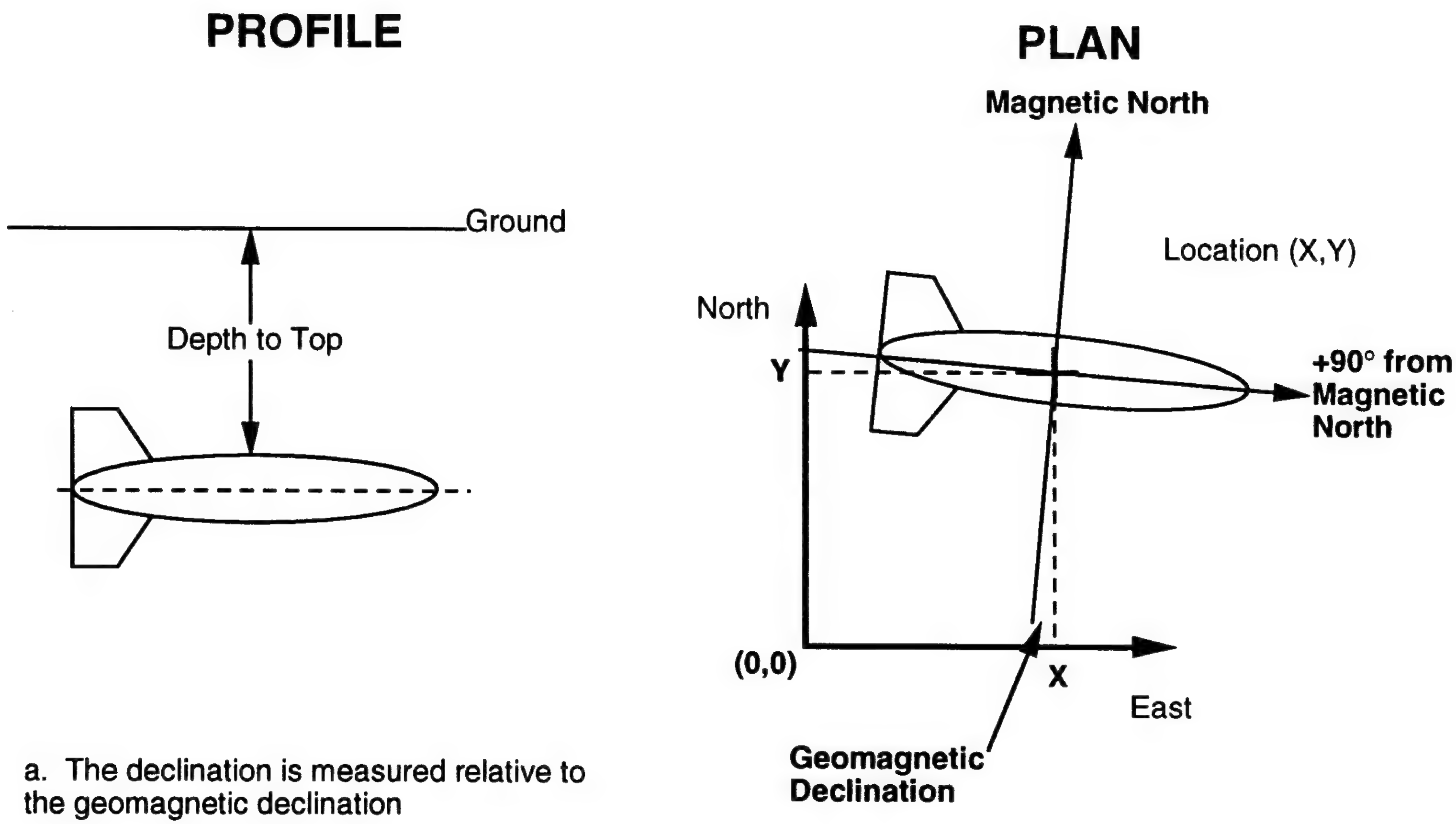


Figure 5.10 Emplacement of UXO, Inclination 0°, Declination 90°.

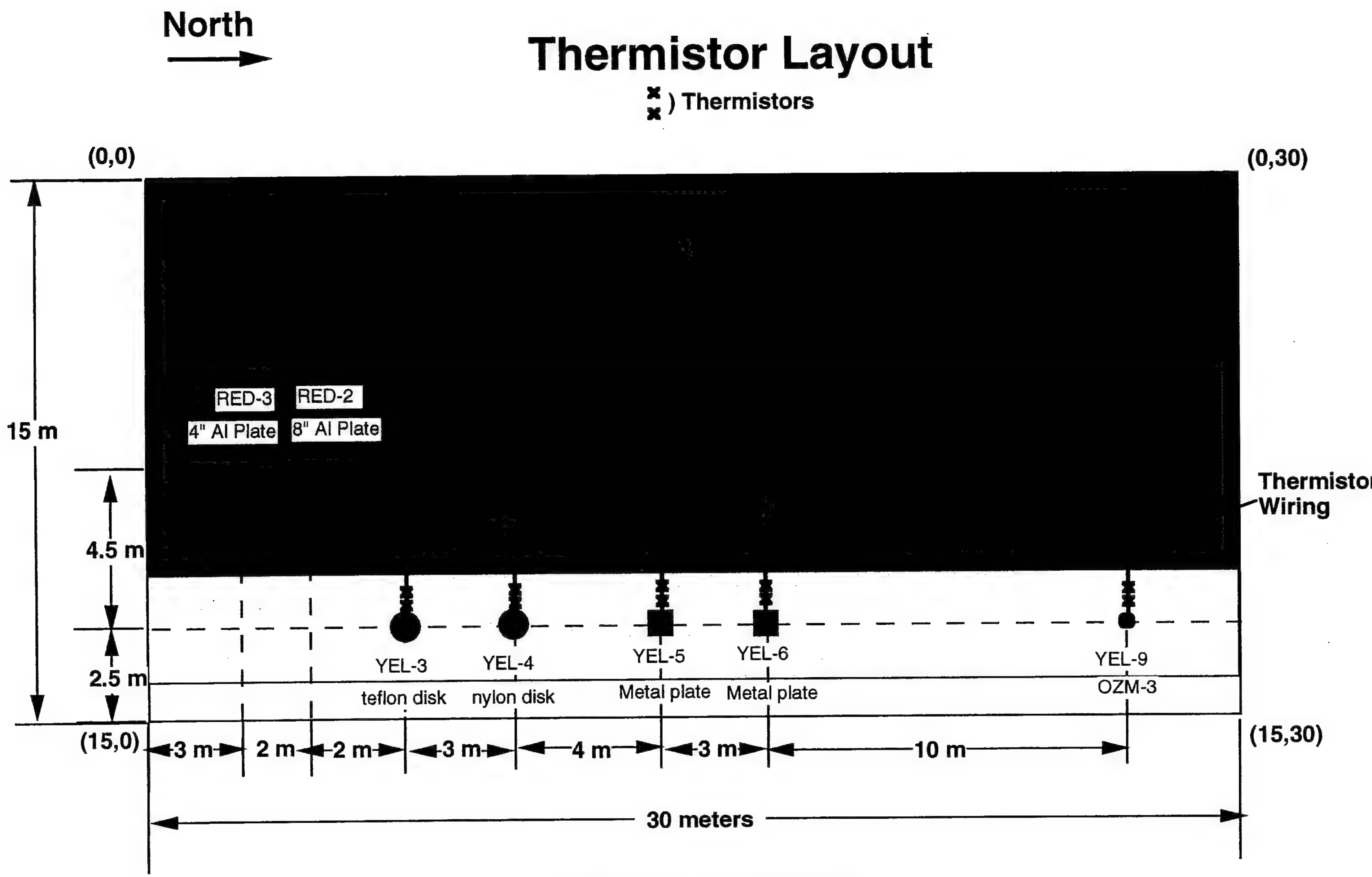


Figure 5.11a Thermistor layout.

FINAL FINAL

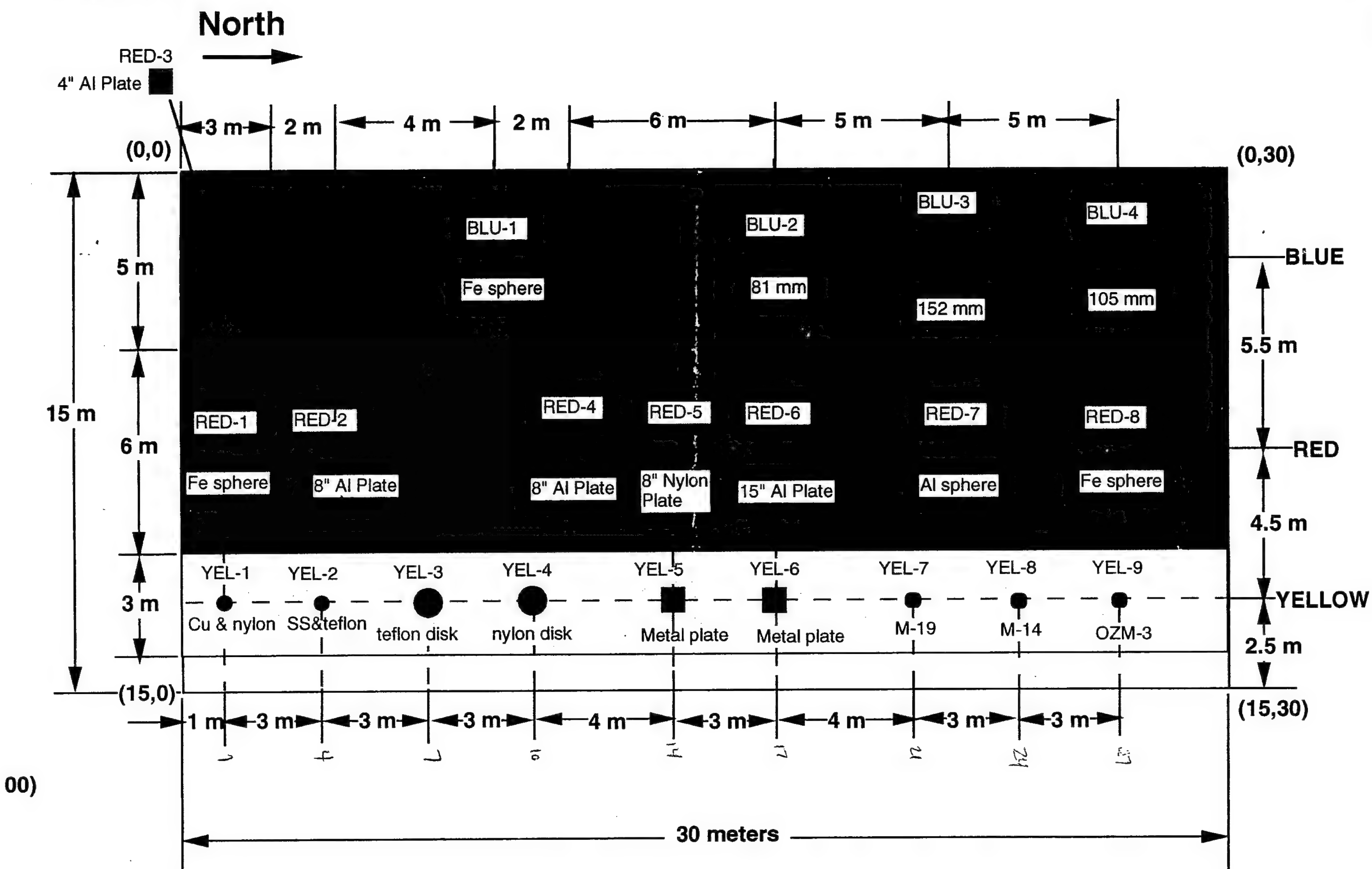


Figure 5.5 Calibration area and targets.

FINAL FINAL

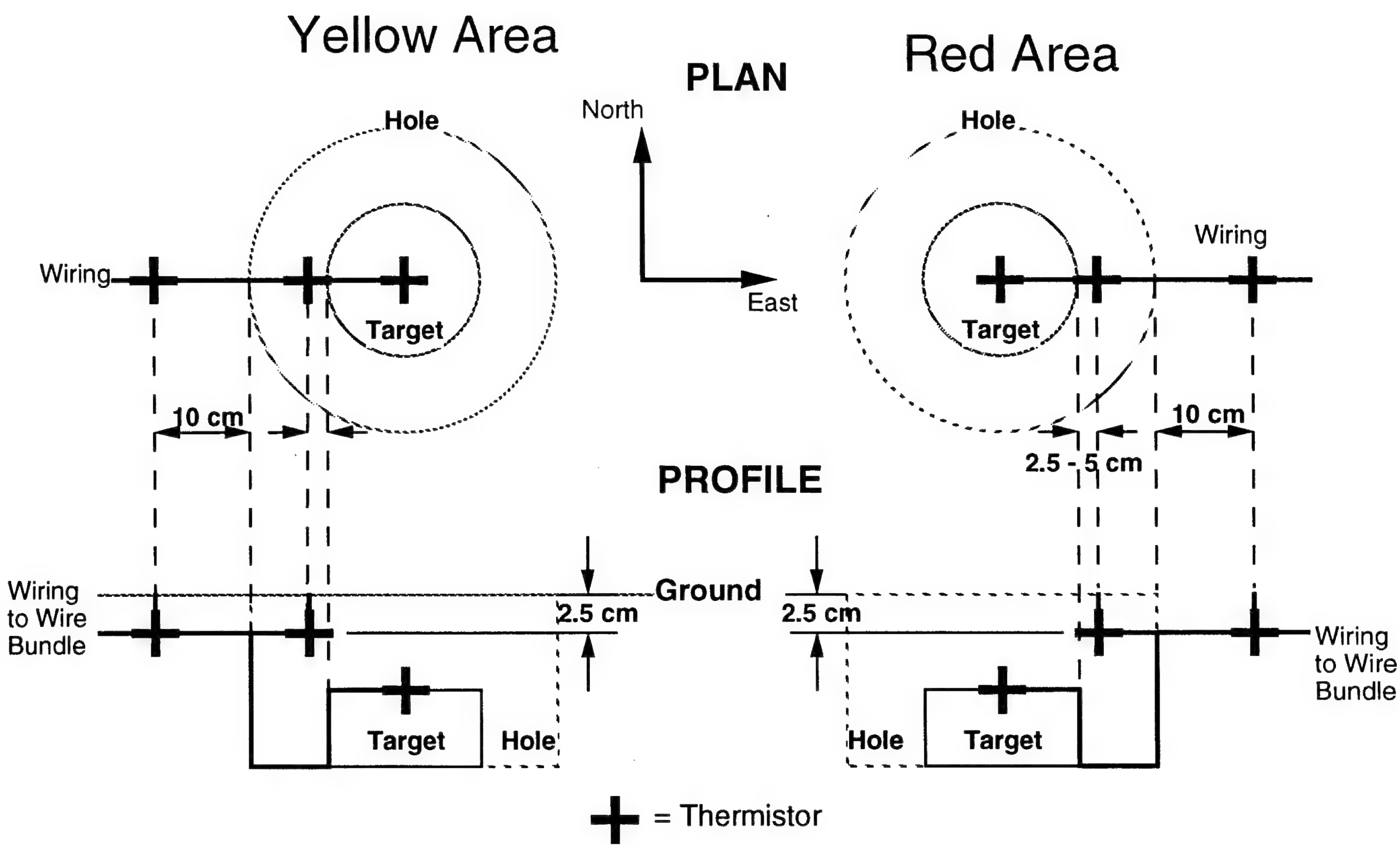


Figure 5.11b Thermistor emplacement.

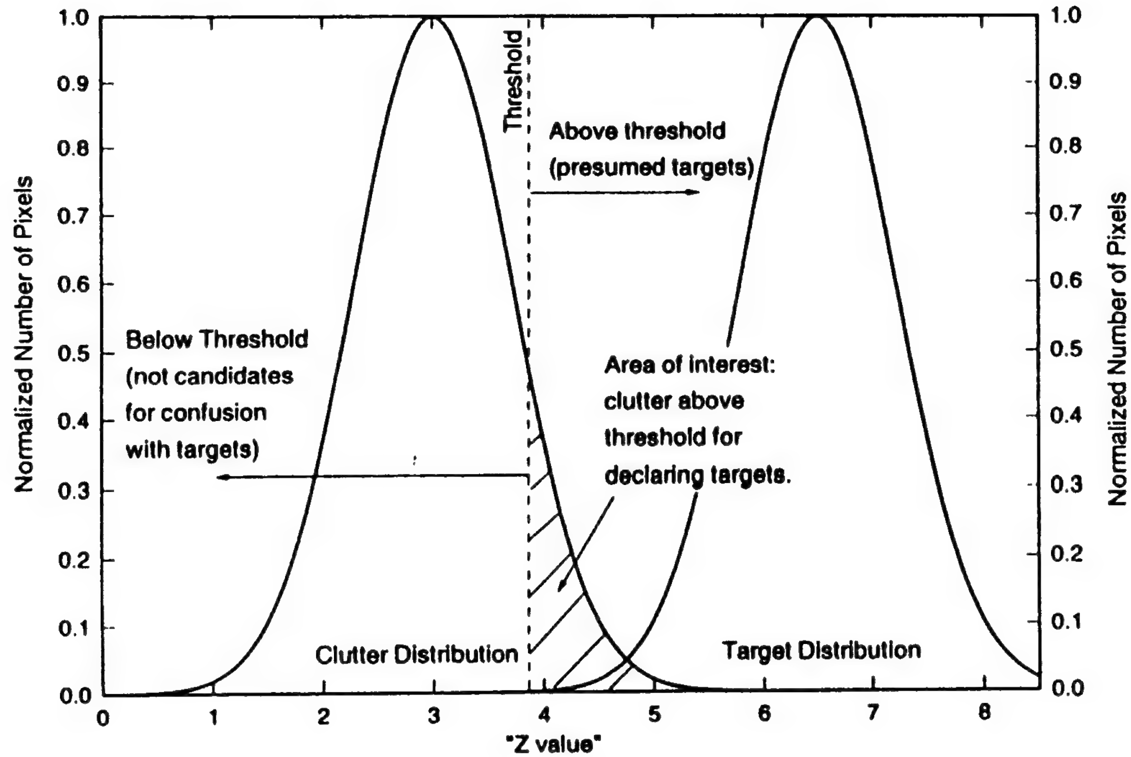
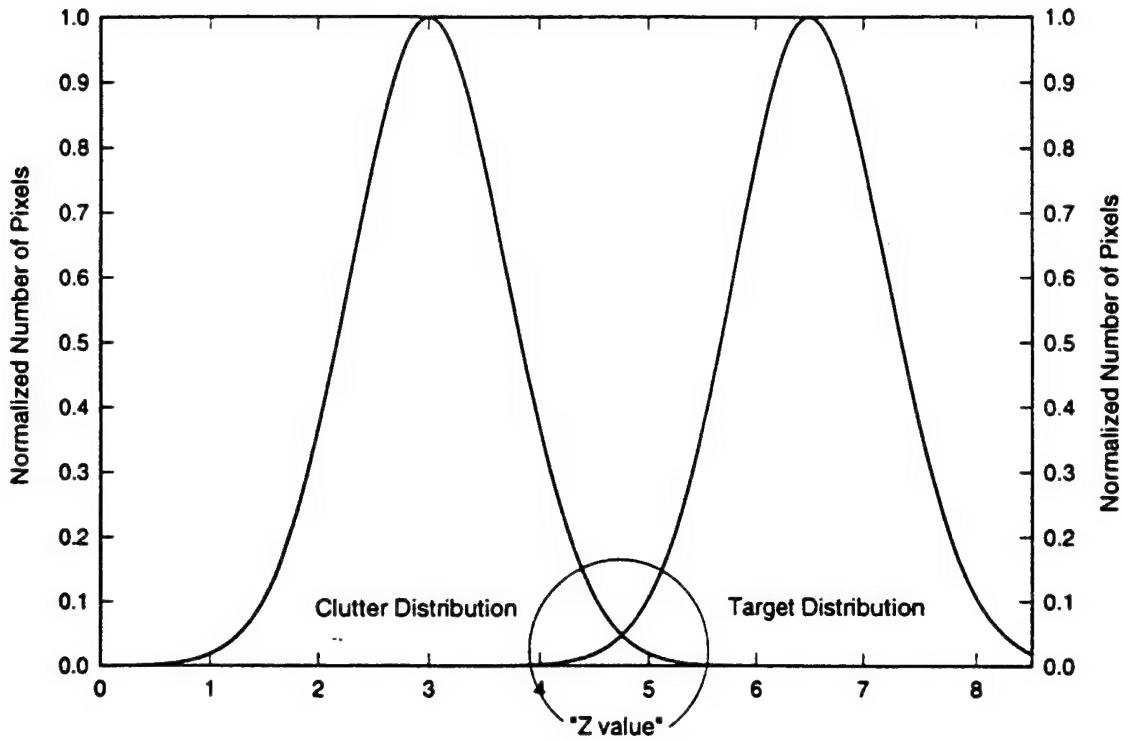


Figure 8.1 Gaussian target and clutter distributions. Assuming a simple thresholding algorithm shows portion of clutter distribution that will be declared targets.



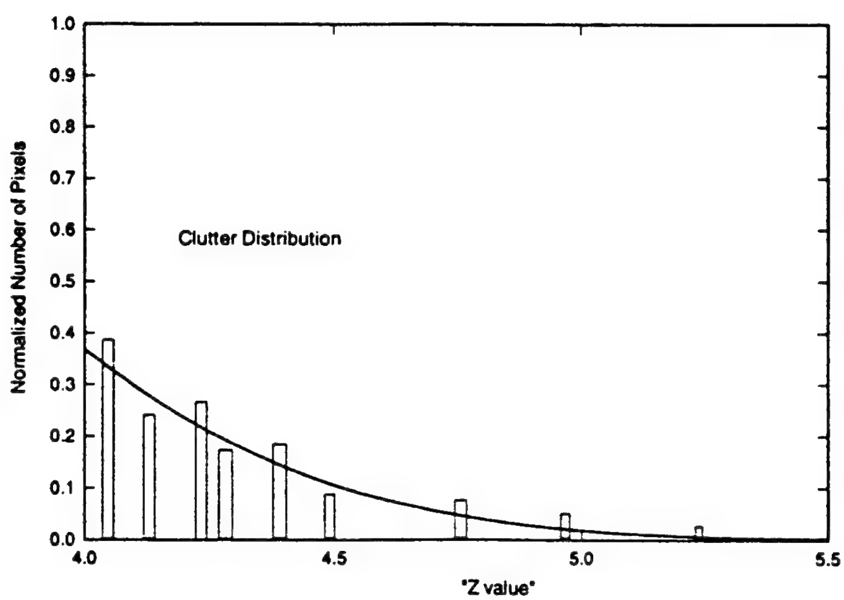


Figure 8.2 Clutter discretes in the tail of the distribution.

Appendix A. Data Collection Forms

This appendix contains copies of all the data collection forms provided for the experiment. Directions for filling out the forms are provided below.

Target Emplacement Data Sheet

One data collection sheet is provided for each target and is to be filled out during target emplacement. Directions for the entries requested are as follows:

Target Serial Number - The serial number is painted on each target.

Target ID - This refers to the target ID used in Appendix E for each target description. The desired entry should be, for example, RED-1, YEL-8, BLU-10, or ORG-5.

Target Description - Some example entries for the target description are as follows: M19 mine, 8" square AL plate, nylon disk, 152 projectile.

Date and Time of Emplacement - This entry is intended to provide information on how long each emplacement takes and as a record of how long it took to emplace the targets on the entire site. This information may help future experiment planning.

Mine Targets - All of the mine targets will be filled with a dielectric explosive simulant (wax or sand). The low metallic mines will have a small piece of metal placed in them, to simulate the firing pin/mechanism. The M19 targets have a red filler; the only thing that needs to be added is the metal surrogate. The filling of the mine with the filler (wax or sand) and the metal may take place any time prior to target emplacement. Regardless of when the filling is done, the information about the filler and the metal content needs to be recorded. The metal type entry refers to the composition of the metal surrogate used; for example, stainless steel (SS), copper (Cu), or both. It is important to record the location of the metal placed in the mine. Acceptable entries might be center and bottom of the mine, or top and northeast side of the mine. The purpose is to provide the relative location of the metal for later induction coil sensor analysis.

Depth of Hole and Depth to Target - The depth of the hole and the depth of the target entries are provided because it may be that the hole is originally too deep and must be backfilled again prior to emplacing the target. The depth of disturbance is desired as well as the depth to the top of the target.

East and North - This refers to the surveyed location of the center of the target relative to the origin on site in meters.

UXO Targets - For UXO targets, the orientation of the target declination relative to the geomagnetic field and inclination relative to the surface needs to be entered. Also, the direction of the geomagnetic field needs to be entered for reference.

Government Supervisor - During the emplacement, a government supervisor will be on site; that person's name should be entered. Questions about the emplacement that arise during the data analysis will be directed to this person.

Comments - This field is provided for any information the emplacer feels is interesting to note. For example, anything in the soil that appears unique, such as, the hole "weeping"

with water, any man-made debris is noticed in the soil taken out of the hole, anything notable about the target, etc.

Event Logs

Two data collection sheets are provided for logging events and keeping a diary during the test. The first allows for entry of the initial results of the sensor detection of the stressing and registration targets; the second is a continuation sheet for recording events and the system settings during testing. The operator is only allowed to change the system settings if the site conditions change. The first sheet must be filled out each time it is necessary to change the system settings. Persons entering information on these sheets (the data collector) must consecutively number the sheets used, and at the end of the survey, the last data collector must enter the total number of pages on each sheet.

Most events will require details about when and where the event occurred. Record the date and time of the event or diary entry. Record where the event occurred as follows: (1) enter the designator on the stake closest to the place where the event occurred and any other positioning data that may help locate the event, (2) make sure that the header information on the data sheet is correct. In the comment field, describe the event and any potential test implications. For example, if the contractor survey is delayed due to inclement weather, you would enter the date and time that the contractor stopped surveying due to the weather, and the designator on the stake closest to the place where the survey stopped. In the comment field, enter "test stopped due to rain, system already behind planned schedule by 2 hours, system was in process of surveying the target side bars for the second time."

Malfunction/ Maintenance Data Collection Sheet

If an event was due to a contractor equipment failure or system malfunction, the Malfunction Data Collection Sheet must be filled out as well.

Backgrounds Clutter Data Collection Program
Target Emplacement Data Sheet

Site (circle one): Firing Point 20   Firing Point 22   Turkey Creek   Seabee

Target Serial Number	
Target ID	
Target Description	
Date of Emplacement	
Time of Emplacement (military)	
Mine Targets	
Location of metal in mine	
Type of metal placed in mine	
Type of filler used	
Diameter of hole	
Depth of hole	
Depth to target	
East (meters from origin)	
North (meters from origin)	
UXO Targets	
Inclination (relative to surface)	
Declination (relative to geomagnetic declination)	
Magnetic Field Inclination	
Magnetic Field Declination	
Government Supervisor	
Comments	

Backgrounds Clutter Data Collection Program
Event Log

Page _____ of _____

Data Collector: ____________________ Contractor:_________________________

Site (circle one): Firing Point 20 Firing Point 22 Turkey Creek Seabee

Detected Stressing Target (Comments)?

Detected Registration Target (Comments)?

Initial System Settings:

Synchronization Time for WES laser tracking system:

Date	Time (military)	Where (designator on stake)	COMMENTS/EVENT/IMPLICATIONS

Backgrounds Clutter Data Collection Program
Event Log (continued)

Page _____ of _____

Data Collector: ___________________ Contractor: ________________________

Site (circle one): Firing Point 20 Firing Point 22 Turkey Creek Seabee

Date	Time (military)	Where (designator on stake)	COMMENTS/EVENT/IMPLICATIONS

Backgrounds Clutter Data Collection Program
Event Log (continued)

Page _____ of _____

Data Collector: ____________________ Contractor: __________________________

Site (circle one): Firing Point 20 Firing Point 22 Turkey Creek Seabee

Date	Time (military)	Notes

Backgrounds Clutter Data Collection Program
Malfunction/ Maintenance Data Collection Sheet

Data Collector: ____________________ **Contractor:** ________________________

Site (circle one): Firing Point 20 Firing Point 22 Turkey Creek Seabee

System: ____
Failure Date: ______________ **Time (military):** ____________________________

Environmental Conditions at Time of Failure:

Description of Malfunction/Failure:

Problem Resolution:

Return to Test Date: ______________ **Time (military):** ___________________

Appendix B. Data Format

The data provided by the contractors must be supplied to the government in Background Standard Format (BSF) or in a data format that has been previously approved by the government. A description of the BSF follows. For each area surveyed, two files will be provided: one contains the header and a second contains the image.[1] The files are to be named with conventional DOS restrictions (8 characters followed by a 3-character extension). The extension for the header file is to be ".hdr" and the extension for the image file is to be ".dat." The header and the image are linked to each other by having identical 8-character names that are unique from other files provided by the contractor.

Background Standard Format

The BSF format consists of the two described above: the first is the header file and the second is the image data file. The format for the ASCII header is shown in Table B.1. The header consists of a series of descriptors followed by the value for the descriptor. The descriptor must appear in the data file exactly as shown with the entry for that descriptor following the ':' in the format specified. The example file shown in Table B.3 should clarify the format expected.

Table B.1 Background Standard Format Header

Descriptor	Format	Entry
Contractor Name:	Text	Company name.
Sensor:	GPR, IR, IC, MAG	Sensor category.
Start Date:	dd:mmm:yyyy:h:min:sec	Date and GMT time of first data point.
End Date:	dd:mmm:yyyy:h:min:sec	Date and GMT time of last data point.
Site Name:	Firing Point 20 Firing Point 22 Turkey Creek Seabee	Enter appropriate site string.
IXRES:	Float	Intended data resolution in centimeters.
IYRES:	Float	Intended data resolution in centimeters.
Site Survey File:	Text	Entry to be provided by DARPA.
System Reference:	Text	Reference to document containing system description.
XOFFSET:	Float	For each sensor enter the difference in X location between WES prism and sensor head in meters. Use a comment to specify which sensor the entry is for.
YOFFSET:	Float	For each sensor enter the difference in Y location between WES prism and sensor head in meters. Use a comment to specify which sensor the entry is for.
SyncTime:	Integer	Synchronization time. This time stamp will be used to synchronize the WES prism data readings. Seconds since start time in header or in the same format as the time entry in the data.
System Settings	Variable	Enter all applicable system settings for the detection of system stressing targets target—note: these settings must match test director's log entries.
Options:[A]	*Variable*	*Description of entry.*
NumZ:	Integer	Number of z values in image.
For each Z		
ZDESC:	Z_N:column header:text	The column header used in the data and a description of the Z value (to include units).
Formula:	*Text*	*How to apply offset.*
ZN_{OFFSET}	*Float*	*Optional for conversion to engineering units.*
END	END	Marks end of header.

[A] Optional fields are entered in *italics*. For all optional entries, a description of the entry is to follow the entry separated by a semicolon. An example BSF header is provided in Table B.3. The number of optional entries is not limited.

The SyncTime entry is intended to aid later data analysis by providing an unequivocal method for assigning X,Y locations of the sensor head (as measured by the WES prism

first time entry tagged in the data and should be in the same format as the data. If the data is provided in BSF format, then the header and the data time entries must be in seconds since the start time listed in the header. If the contractor has a prior agreement with the government to store time in a different format then the T, entry in the data must match the SyncTime entry in format. Furthermore, the first T entry in the data should be the same value as the SyncTime entry in the header.

The XOFFSET and YOFFSET entries in the header are for those systems that will not be able to collocate the WES prism with the sensor head. It is necessary to record the fixed distance from the prism to the sensor head in order to apply the X,Y location data collected by WES. (If the sensor head is collocated with the prism, the entries will be 0.) The contractor will be required to store both an X and a Y offset for each sensor employed. In addition, we ask that the contractor must provide a figure showing the prism, the sensor head, and the distances XOFFSET and YOFFSET. Furthermore, contractors are encouraged to provide a photograph of the system with the mounted prism.

The use of comments in the header is encouraged. Comments are marked by a ';', and continue to the end of the line. Be sure to provide units in the comments.

The image data are to be provided in ASCII format in columns separated by one space. The first row in the file are the column headers: T, X, Y, Z_1,Z_2,Z_3, . . . Z_N. The commas are for description only and do not appear in the data (the data is single-space separated). A sample file in the format described is provided in Table B.3. A description of each column is provided in Table B.2.

Table B.2 Background Standard Format Image

Column	Format	Entry
T	Integer	Seconds since start time in header.
X	Float	Meters to east of reference point in the header.
Y	Float	Meters to north of reference point in the header.
Z_N	Float	N^{th} component of data vector from system.

Table B.3 Example Background Standard Format Header and Image

aaa_fp22.hdr

Contractor Name: AAA EM Incorporated
Sensor: IC
Start Date: 01:SEP:1996:1600:43:52
End Date: 04:SEP:1996:1300:10:03
Site Name: Firing Point 22
IXRES: 50 ; cm between survey lines
IYRES: 10 ; cm along the direction of travel
Site Survey File: "Site Characterization for Fort AP Hill," Waterways Experiment Station, 1996
System Reference: "AAA EM System Specifications," AAA EM Incorporated, 1994
XOFFSET: 1.2 ;distance to the left most coil as viewed by vehicle driver
YOFFSET: 0.5 ;distance to the left most coil as viewed by vehicle driver, each coil is separated by 0.2 meters.
Frequency: 9.8kHz ; The system frequency setting used to see the system stressing target

NumZ: 4
ZDESC: Z1:IC1:first IC coil
Formula: $newZ_1 = (Z_1 + Z_{OFFSET})*2.7456$ to convert to units of mS/m
$Z1_{OFFSET}$: 1245.2587
ZDESC: Z2: IC2:second IC coil
Formula: $newZ_2 = (Z_2 + Z_{OFFSET})*2.7456$ to convert to units of mS/m
$Z2_{OFFSET}$: 1245.2587
ZDESC: Z3: IC3:third IC coil
Formula: $newZ_3 = (Z_3 + Z_{OFFSET})*2.7456$ to convert to units of mW
$Z3_{OFFSET}$: 1245.2587
ZDESC: Z4: IC4:fourth IC coil
Formula: $newZ_4 = (Z_4 + Z_{OFFSET})*2.7456$ to convert to units of mW
$Z4_{OFFSET}$: 1245.2587
END

aaa_fp22.dat

T	X	Y	IC1	IC2	IC3	IC4
000000	NUM	NUM	NUM	NUM	NUM	NUM
000000	NUM	NUM	NUM	NUM	NUM	NUM

.
.
.

where NUM = ±X.XXXE±XX.

The data collected for the entire site may be segmented and submitted in more than one file. The smallest acceptable segment for a single image is 10 x 10 meters. Submitting the data in 10 x 10 meter segments would result in 100 files per site; a total of 400 files for the 2 locations. If a contractor chooses to segment the image, the method of segmentation must be described and a file-naming convention must be adhered to that allows for simple translation of a file to a location on the site. Furthermore, a map must be provided that shows the segmentation and relates file names provided to areas on the map.

Three acceptable ways to provide data are listed as follows in order of preference:

1) CD ROM written in ISO9660 format.
2) PC format Zip cartridges. A single zip cartridge holds 100 MB and costs about $17.00. A Zip drive costs $199.95.
3) PC format 8-mm tape. An 8-mm tape drive costs ~$1800.00 and 8-mm tape costs between $10.00 & $26.00.
4) If submitting the data in the above format or on the specified media is not practical or causes the contractor undue expense or hardship, a different data format or media can be used with prior permission from the government. In order for the government to approve such changes the request must be made in writing prior to August 12, 1996.

If the contractor chooses to compress the data using compression software, the uncompression software must be provided with the data.

The calculations made to arrive at the above formatting and media requirements are as follows. Maximum expected resolution is 10 cm. The site size is a hectare or 1,000,000 pixels of size 10 x 10 cm. To obtain this high resolution, a contractor may elect to survey

represent each data point is 11 (±X.XXXE±XX[tab]). The number of digits necessary to store the time field is 6 digits (5 days = 432000 seconds). If we assume that a contractor supplies us with an image two times as large as the optimal 1,000,000 data points, then the total image size for one hectare is: 1,000,000 x 6 x 11 x 2 (+ 1,000,000 x 6 x 2) = 144,000,000 bytes = 144 MB.

Disclaimer: DARPA does not claim responsibility for the quality of the products or services listed. The product information is provided for informational purposes only and does not constitute an endorsement of any of these products.

Appendix C. Maps & Hotels

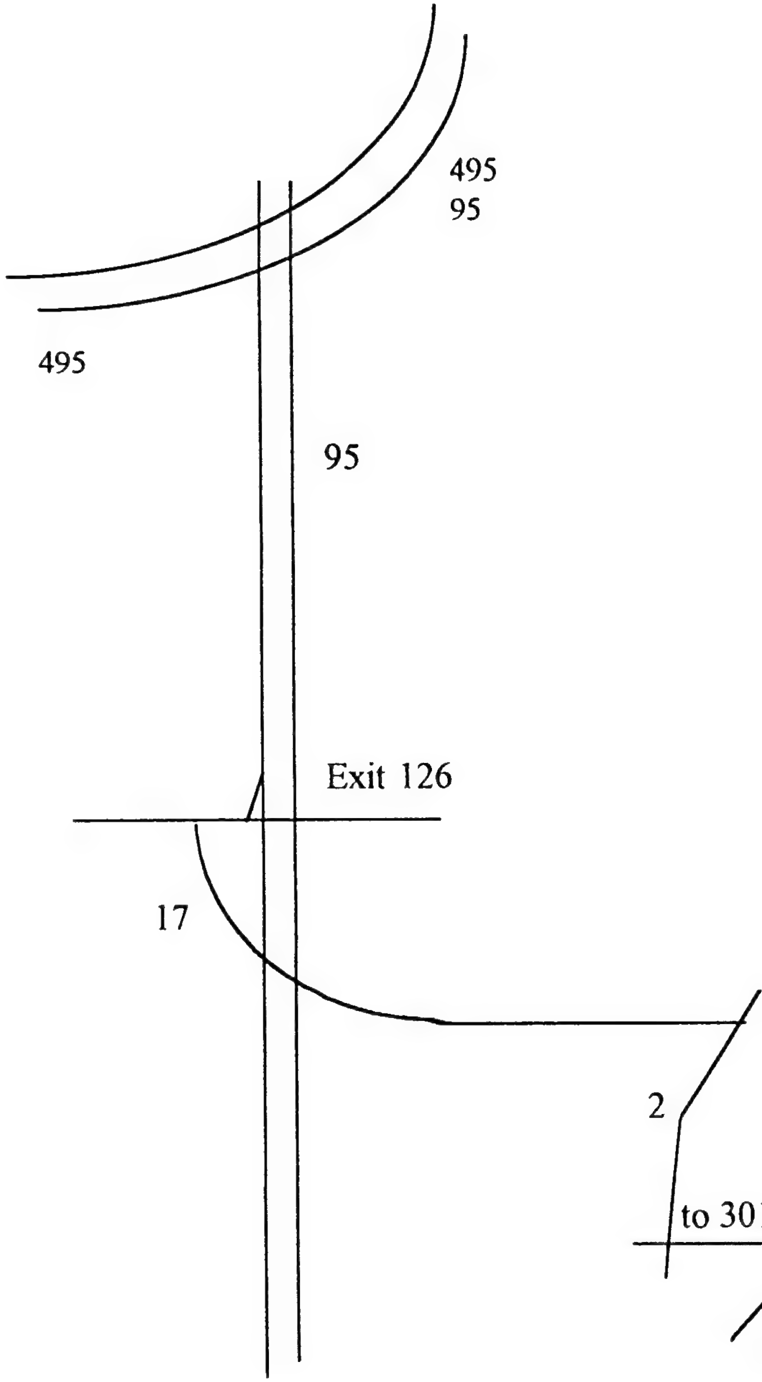
Hotels in Fredericksburg, Virginia.

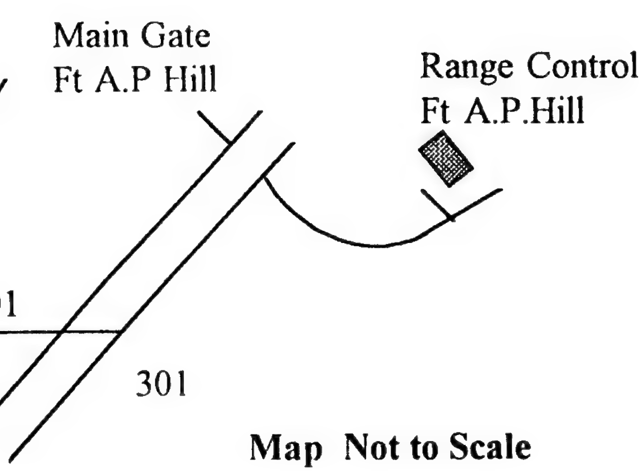
Holiday Inn (540) 898-1102
Comfort Inn (540) 898-5550
Wytestone Suites (540) 891-1112
Hampton Inn (540) 371-0330

TO FORT A.P. HILL

- Take 95 S towards Richmond
- Take exit 126 to Massaponax
  Go right at bottom of exit to Rt 17 south
- Take a left at second light (past Travel Plaza)
  on 17 south also called Mills Rd
- Go six miles south on Rt 17
  turn right at blinking lights on
  Rt 2 south to Bowling Green
- Go 14 miles on Rt 2, turn left at light to 301 North
  Go approx 1/4 mile and turn left at second stop sign
  on 301 North
- Go a mile or two North on 301 and turn right (NOT LEFT)
  into Ft A.P. Hill
- Range Control is first building on Left

Everyone must stop and check in at Range Control

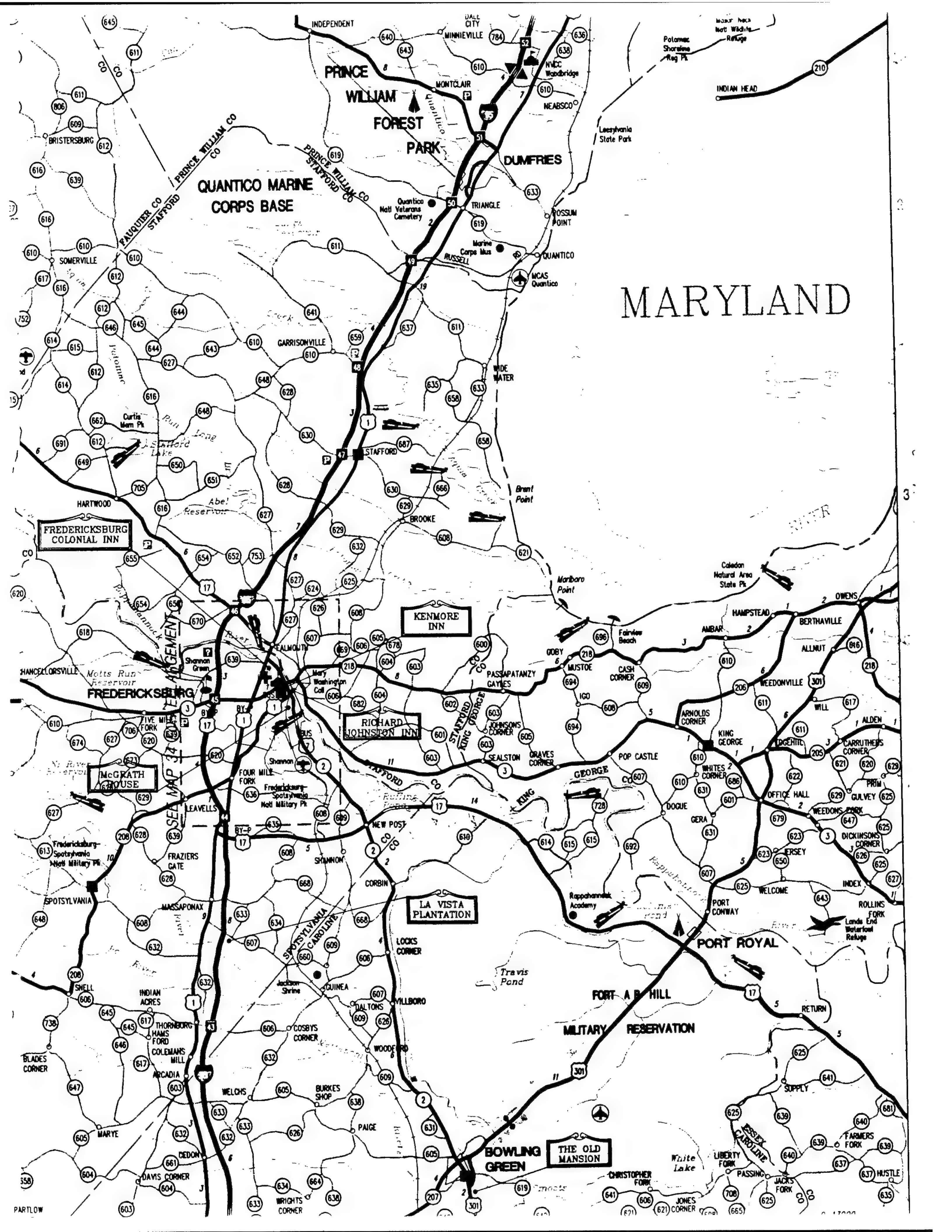




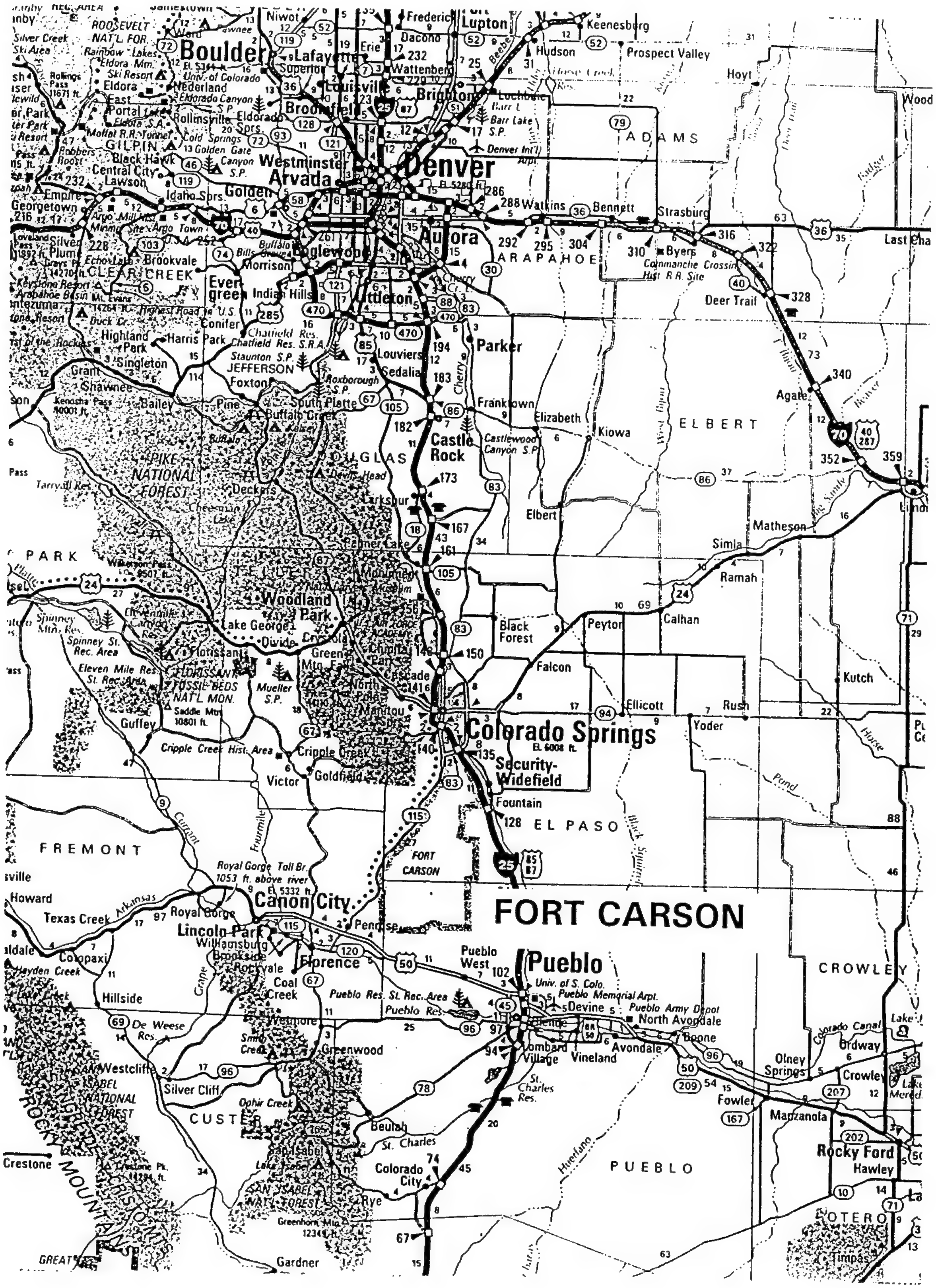
Map Not to Scale

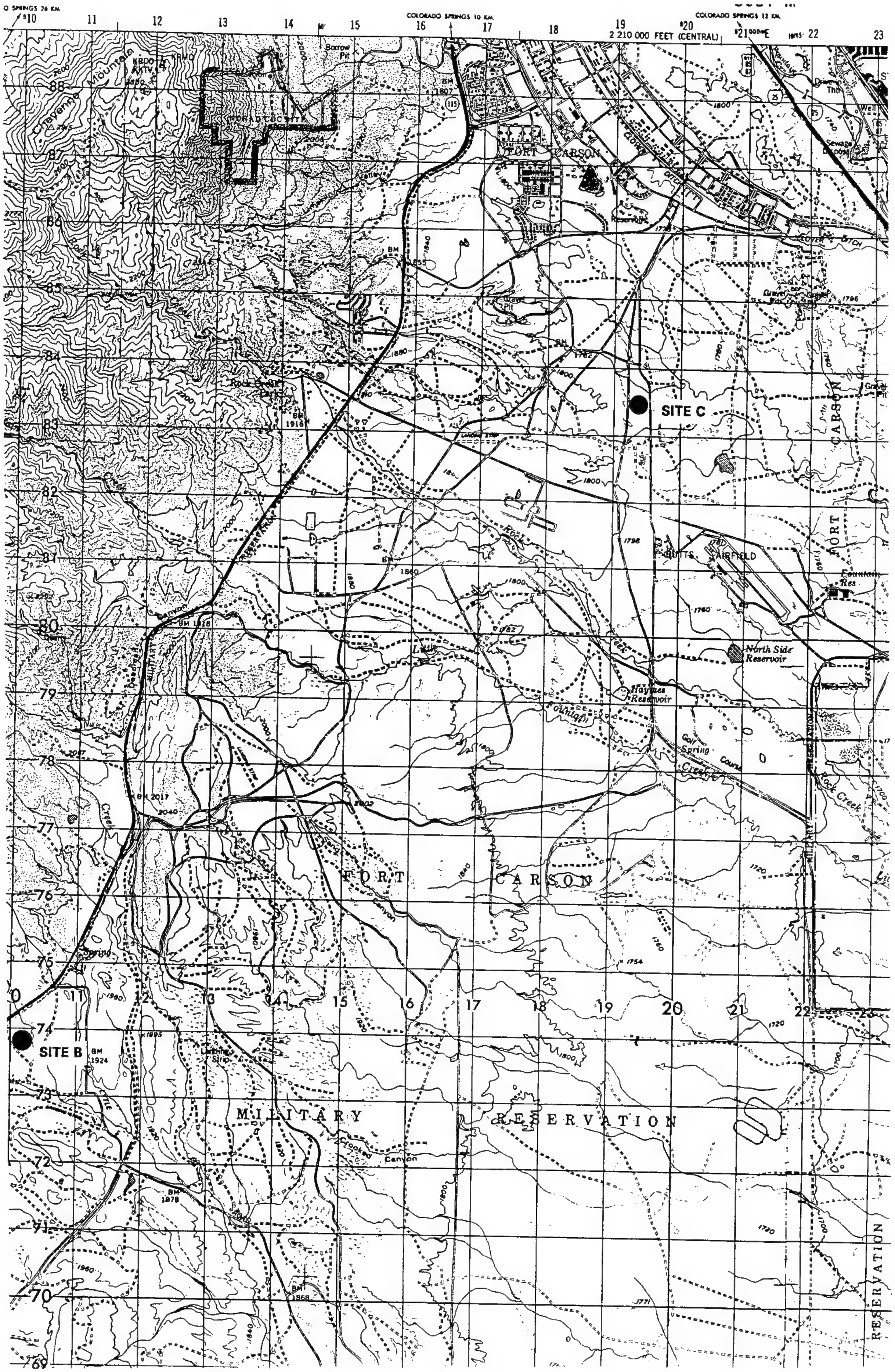
Approximate Distances

Richmond to Fredericksburg 58 miles
Washington D.C. to Federicksburg 68 miles



INDEPENDENT
DALE CITY
MINNIEVILLE
Potomac Shoreline Reg Pk
Mason Neck Natl Wildlife Refuge
NVCC Woodbridge
INDIAN HEAD
PRINCE WILLIAM FOREST PARK
MONTCLAIR
NEABSCO
Leesylvania State Park
BRISTERSBURG
DUMFRIES
PRINCE WILLIAM CO
STAFFORD CO
FAUQUIER CO
QUANTICO MARINE CORPS BASE
Quantico Natl Veterans Cemetery
TRIANGLE
POSSUM POINT
Marine Corps Mus
QUANTICO
SOMERVILLE
RUSSELL
MCAS Quantico
MARYLAND
GARRISONVILLE
WIDE WATER
Curtis Mem Pk
Stafford Lake
STAFFORD
Abel Reservoir
Brent Point
HARTWOOD
BROOKE
FREDERICKSBURG COLONIAL INN
Caledon Natural Area State Pk
Marlboro Point
OWENS
HAMPSTEAD
BERTHAVILLE
KENMORE INN
AMBAR
Fairview Beach
FALMOUTH
ALLNUT
GOBY
MUSTOE
CASH CORNER
PASSAPATANZY
GAYLES
Shannon Green
CHANCELLORSVILLE
Motts Run Reservoir
FREDERICKSBURG
Mary Washington Coll
WEEDONVILLE
IGO
ARNOLDS CORNER
KING GEORGE
WILL
ALDEN
RICHARD JOHNSTON INN
JOHNSONS CORNER
FIVE MILE FORK
EDGEHILL
CARRUTHERS CORNER
SEALSTON
GRAVES CORNER
POP CASTLE
McGRATH HOUSE
WHITES CORNER
PRIM
FOUR MILE FORK
Fredericksburg-Spotsylvania Natl Military Pk
Shannon
OFFICE HALL
GULVEY
WEEDONS FORK
LEAVELLS
DOGUE
GERA
DICKINSONS CORNER
NEW POST
JERSEY
FRAZIERS GATE
SHANNON
CORBIN
WELCOME
INDEX
ROLLINS FORK
SPOTSYLVANIA
LA VISTA PLANTATION
Rappahannock Academy
PORT CONWAY
MASSAPONAX
Lands End Waterfowl Refuge
PORT ROYAL
LOCKS CORNER
Travis Pond
SNELL
Jackson Shrine
GUINEA
INDIAN ACRES
DALTONS
MILLBORO
FORT A P HILL MILITARY RESERVATION
RETURN
THORNBURG
HAMS FORD
COSBYS CORNER
BLADES CORNER
COLEMANS MILL
WOODFORD
ARCADIA
SUPPLY
WELCHS
BURKES SHOP
MARYE
PAIGE
FARMERS FORK
CEDON
BOWLING GREEN
THE OLD MANSION
LIBERTY FORK
White Lake
DAVIS CORNER
CHRISTOPHER FORK
PASSING
JACKS FORK
HUSTLE
WRIGHTS CORNER
JONES CORNER
PARTLOW
ESSEX
CAROLINE
SEE MAP 34 FOR ENLARGEMENT


FORT CARSON
Boulder
Denver
Arvada
Westminster
Aurora
Englewood
Littleton
Golden
Brighton
Louisville
Broomfield
Lafayette
Longmont
Keenesburg
Prospect Valley
Hudson
Hoyt
Watkins
Bennett
Strasburg
Byers
Deer Trail
Agate
ADAMS
ARAPAHOE
ELBERT
DOUGLAS
Parker
Castle Rock
Franktown
Elizabeth
Kiowa
Elbert
Matheson
Simla
Ramah
Calhan
Peyton
Black Forest
Falcon
Ellicott
Rush
Yoder
Kutch
Colorado Springs
Security-Widefield
Fountain
EL PASO
FORT CARSON
Monument
Palmer Lake
Woodland Park
Divide
Lake George
Florissant
Cripple Creek
Victor
Goldfield
Manitou Springs
Guffey
PARK
FREMONT
Canon City
Royal Gorge
Florence
Penrose
Lincoln Park
Williamsburg
Brookside
Rockvale
Coal Creek
Howard
Texas Creek
Cotopaxi
Hillside
Westcliffe
Silver Cliff
CUSTER
Pueblo
Pueblo West
Devine
North Avondale
Avondale
Boone
Vineland
Beulah
Colorado City
Rye
Gardner
Crestone
PUEBLO
CROWLEY
Olney Springs
Ordway
Crowley
Fowler
Manzanola
Rocky Ford
Hawley
OTERO
Timpas
Evergreen
Conifer
Bailey
Pine
Deckers
Sedalia
Louviers
Idaho Springs
Central City
Black Hawk
Georgetown
Empire
Nederland
Eldora
PIKE NATIONAL FOREST
SAN ISABEL NATIONAL FOREST



N

Fort Carson

Site C - Seabee

Site B - Turkey Creek

FORT CARSON/COLORADO Springs, CO

ACCOMMODATIONS

ne Sawatzki

When Colorado's first governor journeyed to the Springs years ago, Henry McAllister's cottage was one of Colorado's few decent places to stay. Things have changed. The region now boasts plentiful accommodations from nationally familiar to locally charming that cater to all budgets and comfort levels. Enscence yourself at the elegant Broadmoor Hotel to play golf, nibble filet mignon and fine pastries, or doze by the lake. Settle into a Manitou Springs family motel with a relaxing pool and handy kitchenette. Some accommodations provide in-house conference rooms, health clubs, and their own distinctive brand of culinary treasures. Local bed & breakfasts lavish soothing antidotes to everyday stress, and rustic cabins offer peaceful retreats from hectic schedules. Whether your visit is brief or extended, your home away from home should suit your fancy. ■

Hotels & Motels

Area	Hotels & Motels	Number of Rooms	Range of Rates	Kitchenettes/Suites	Restaurants/Lounges	Pool	Hot Tub/Spa	Pets Allowed	Exercise Room	Air Conditioning	Major Credit Cards	Description
CENTRAL	**Alikar Gardens Resort** 719-475-2564 1123 Verde Drive Suite D 80910-2199	121	Call		0/1	Out	●		●	●	●	800-456-1123 800-666-9997 daily, weekly, monthly rates
	Antlers Doubletree Hotel 800-222-8733 4 S. Cascade Ave., Co Spgs, CO 80903	290	Call		2/2	In	●	●	●	●	●	Downtown location, excellent views of Pikes Peak
	Best Western Le Baron Hotel 719-471-8680 314 West Bijou St., Co Spgs, CO 80903	206	Call	●	1/1	Out		●	●	●	●	Toll Free 1-800-477-8610 Downtown I-25 at Bijou St.
	Dale Motel 636-3721 800-456-3204 620 W. Colorado Ave., Co Spgs, CO 80905	28	Call	●		Out				●	●	Near restaurants, attractions & groceries/AAA/Cablevision
	Econo Lodge Dntn 636-3385 800-553-2666 714 N Nevada I-25 Exit 143, Rt on Nevada	38	$40-$65	●		Out	●			●	●	Free cont. breakfast, cable, nonsmoke, cent all maj attract
	Hearthstone Inn 473-4413 1-800-521-1885 506 N. Cascade Ave., Co Springs 80903	23	$62-$148	●						●	●	Country Inn/nat'l hist. bldg gourmet bfast incl/FPs/porch
	Holden House Bed & Breakfast Inn 471-3980 1102 W. Pikes Peak Ave. Co Spgs, 80904	6	$75-$110	S						●	●	Victorian Inn-phones-fax-tubs for 2-fireplaces-AAA-mobil
	Holiday Inn Express 473-5530 8th & Cimarron 7 Hwy 24 -Kitchenettes-	207	$35-$85	●		Out		●		●	●	Complimentary breakfast bar close to Old Colorado City
	J's Motor Hotel 633-5513 800-472-6009 820 N Nevada Ave Colorado Springs 80903	50	$34-$55		1/0	Out		●		●	●	1 block from Co College/near downtown / AARP discount
	Rodeway Inn 719-471-0990 2409 E. Pikes Peak Ave Co Spgs CO 80909	113	$47-$70	●	1/1	Out		●		●	●	Excellent view of Pikes Peak close to all attractions
	Room at the Inn B&B - 719-442-1896 618 N Nevada Co Spgs 80903 800-579-4621	7	$80-$110	●	0/2		●			●	●	Elegant 3 story inn, antiques tubs for two, fireplaces, fax
	Travel Inn Motel 636-3986 512 S. Nevada Ave Colorado Springs 80903	36	$28-$65							●	●	AAA rated/ near attractions/ downtown/restaurants/coffee
EAST	**Alikar Gardens Resort** 719-475-2564 1123 Verde Drive Suite D 80910-2199	121	Call		0/1	Out	●		●	●	●	800-456-1123 800-666-9997 daily, weekly, monthly rates
	Apollo Park Executive Suites 634-0286 805 S Circle #2B CoS 80910 800-666-1955	87	Call	●		Out		●	●	●	●	Full kitchens, fully furnished 1&2 bdrms AAA day week month
	Comfort Inn 1-800-228-5150 380-9000 2115 Aerotech Dr., Co Spgs, CO 80916	42	Call	●		In	●		●	●	●	Continental breakfast/airport shuttle / closest to airport
	Heidelberg Motel 636-5261 2105 E. Platte Ave. Co Spgs, CO 80909	15	Call	●						●	●	Quiet picnic area/ near OTC, Memorial Hosp., restaurants
	Radisson Inn Co Spgs Airport 597-7000 1645 Newport Rd., Co Spgs, CO 80916	145	$90-$145		1/1	In	●	●	●	●	●	Full service airport hotel mini suites - 597-7000
	Super 8 Motel Hwy 24 at Peterson Rd. 605 Peterson Rd 80915 597-4100	44	Call							●	●	Continental breakfast/near restaurants/kings available
	Value Inn - Peterson AFB 800-596-5588 US Hwy 24 at Peterson Road East	73	Call	●	4/1					●	●	Free movies/coffee, on-site laundry, value club rates
NORTH	**Bel Air Motel** 598-7057 Res.800-647-2002 4000 N. Nevada Ave., Co Spgs, CO 80907	15	$32-$65	K		In				●	●	Cablevision/phones/laundry picnic area/near USAF & dog tr
	Best Western Palmer House 800-223-9127 3010 Chestnut St., Co Spgs, CO 80907	150	$44-$88	●	1/1	Out		●		●	●	10 min to major attractions meeting/banquet space
	Colorado Springs Marriott 260-1800 5580 Tech Center Dr Co Springs CO 80919	310	$89-$149	●		In Out	●		●	●	●	Beautiful mountainside location near all attractions
	Days Inn, North 719-598-1700 4610 Rusina Road, Colo. Spgs. CO 80907	64	Call		1/1	Out				●	●	Free continental breakfast guest laundry
	Drury Inn 598-2500 800-325-8300 8155 N. Academy Blvd. 80920 Exit 150A	118	Call	●		In Out	●	●	●	●	●	Free quickstart breakfast & local calls/disc, AAA & AARP
	Embassy Suites Hotel 599-9100 7290 Commerce Center Dr., Co Spgs 80919	207	$79-$139	●	1/1	In	●		●	●	●	Complimentary full breakfast & cocktails / in-room coffee
	Frontier Motel 719-598-1563 4300 N. Nevada Ave. Co Spgs CO 80907	28	$35-$68	●		Out				●	●	All rooms have microwave & refrigerator, phone, cable TV
	Hampton Inn North 593-9700 800-HAMPTON 7245 Commerce Center Dr. 80919 Exit-149	128	Call			In		●		●	●	Continental breakfast/seasonal happy hr/inroom coffee & irons
	Holiday Inn Garden of the Gods 598-7656 505 Popes Bluff Tr., Co. Springs 80907	200	$59-$99	●	1/1	Out	●	●	●	●	●	Free airport transportation/ free HBO/Golf club privileges
	Holiday Inn North 633-5541 Exit 145 3125 Sinton Rd -meeting facilities-sauna	220	$45-$95	●	1/1	In		●		●	●	Indoor heated pool, mountain view, restaurant, group rates
	Howard Johnson Lodge 800-654-2000 5056 N. Nevada Ave. Exit 148A 598-7793	50	Call			Out				●	●	Free continental breakfast/ airport shuttle/near dining
	La Quinta Inn 528-5060 800-531-5900 4385 Sinton Rd., Co Springs 80907	105	$39-$101	●		Out		●		●	●	Continental breakfast/ near Garden of the Gods & USAFA

The area code for the Colorado Springs/Pikes Peak Region is 719.

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Hotels & Motels

	Number of Rooms	Range of Rates	Kitchenettes/Suites	Restaurants/Lounges	Pool	Hot Tub/Spa	Pets Allowed	Exercise Room	Air Conditioning	Major Credit Cards	Description
NORTH cont.											
Motel 7 635-5486 3402 Sinton Rd. 80907 I-25 Exit 145	42	$29-$69	•						•	•	10 min. from downtown & AFA/ free local calls & coffee
Peak View Inn 719-598-1545 800-551-2267 4950 N. Nevada Ave., Colo Springs CO 80918	80	$24-$80	•		Out	•			•	•	Day/week/month/rates/kitchen free calls/ cable movies/Disc
Quality Inn Garden of Gods 719-593-9119 555 W Garden of Gods, Co Spgs, CO 80907	157	Call			Out				•	•	Continental breakfast, nearby restaurants, free local calls
Radisson Inn Co. Springs North 598-5770 8110 North Academy Blvd, 800-333-3333	200	$65-$250	S	1/1	In	•	•	•	•	•	Lush atrium with trees & plants & sparkling fountains
Red Roof Inn 719-598-6700 8280 Highway 83, Co Spgs CO 80920	110	Call			Out				•	•	Excellent rates year-round dining, shopping nearby
Residence Inn by Marriott 719-574-0370 3880 N. Academy Blvd, Co Spgs, CO 80917	96	Call	•		Out	•	•		•	•	Movie theatres / restaurants within walking distance
Star Motel 598-4044 3920 N. Nevada, Co Spgs, CO 80907	29	Call	•						•	•	BBQ-picnic area/refrigerator & microwaves in room/cable
Super 8 Air Force Academy 528-7100 8135 N. Academy I-25 Exit 150A	33	$39-$79	•						•	•	Adjacent to USAFA/free local calls, tea & coffee/cable TV
Super 8 Chestnut 632-2681 3270 N.Chestnut 80907 I-25 Exit 145	32	$29-$79	•						•	•	10 min. from USAFA & Garden of Gods / Free local calls
Super 8 Garden of the Gods 594-0964 I-25 & Garden of the Gods Rd Exit 146	51	$39-$89	•						•	•	10 min. from USAFA & Garden of Gods / Free local calls
SOUTH											
The American Inn - 800-632-7077 1703 S. Nevada, Colorado Spgs, CO 80906	80	$45-$65		1/0	Out				•	•	New rooms/DD ph/cable tv/ baby pool/close to attractions
Bighorn Lodge Ltd. 632-7658 1018 S. Nevada, Colorado Springs CO 80903	16	$35-$80					•		•	•	Mini-kitchens / cable / near attractions & restaurants
The Broadmoor Hotel 719-634-7711 One Lake Ave. Colorado Springs CO 80906	700	Call		9/5	In Out	•	•	•	•	•	Three 18-hole golf courses, tennis, 28 shops, full spa
Budget Inn 719-576-2371 1440 Harrison Road Co Spgs CO 80906	43	$30-$80							•	•	Budget priced luxury unit rest. next door, tub shower
Cañon Inn of Cañon City 275-8676 3075 E. Hwy 50 Cañon City 81212	152	Call	•	2/1	Out	•	•		•	•	AAA/group rates/800-525-7727 AARP discount/HBO w remote
Chateau Motel 575-0809 Near US 24 & I-25 1201 S. Nevada Ave., Colorado Springs	41	$30-$50	•						•	•	Non-smoking rooms / near attractions/cable/new rooms
Cheyenne Mountain Inn 800-428-8886 3225 Broadmoor Valley Rd Co Spgs 80906	278	Call		2/2	In Out	•		•	•	•	250 acre resort, golf, tennis, racquet sports
Chief Motel - 719-473-5228 1624 S. Nevada Ave, Co Spgs, CO 80906	25	Call	•			•	•		•	•	AAA, phones, 40 ch cable TV patio by stream, dining nearby
Days Inn South 719-527-0800 2850 S. Circle Dr. Colo Springs, CO 80906	126	Call		1/1	In Out				•	•	Full service hotel banquet facilities
Economy Inn 634-1545, 1-800-235-1545 1231 S. Nevada I-25 Exit 140A S., 140B N.	43	$35-$55	•		Out	•			•	•	AAA appr, non smok, cable, phon free coffee, near all maj att
Econo Lodge 632-6651 1-800-55-ECONO 1623 S. Nevada Ave, Exit 140A/140B	50	Call	•		Out				•	•	Recreational facilities/ AM coffee/ close to attractions
Hampton Inn South 719-579-6900 1410 Harrison Rd. Co Spgs., CO 80906	116	Call			In	•			•	•	Limited service hotel
Red Lion Hotel - 800-547-8010 1775 East Cheyenne Mountain Boulevard	299	Call	•	1/2	In	•	•	•	•	•	Newly renovated, oversized rooms with only queens/kings
The Satellite Hotel (800) 423-8409 411 Lakewood Circle, Co Spgs	76	Call	•	1/0	Out			•	•	•	Quiet relaxing full-service accommodations family/corp
Sheraton Colorado Springs Hotel 2886 S. Circle Dr. 800-576-5470	500	Call		2/1	In Out	•		•	•	•	Newly renovated convention hotel., 30 meeting rooms.
Travelers Uptown Motel 719-473-2774 220 E. Cimarron, Co Spgs, CO 80903	46	Call			Out				•	•	Close to Downtown Hwy 24 goes by our door
WEST											
Alpine Motel 685-5455 Res: 800-289-5455 45 Manitou Ave, Manitou Springs CO 80829	25	$49.50-115.50	•		Out				•	•	Family units/near attraction & restaurants / AAA rated
Amarillo Motel 719-635-8539/800-216-8539 2801 W. Colorado Ave., Co Spgs 80904	30	$28-$50	•				•		•	•	Family units/room ph/cableTV Hosts: Elden & Sylvia Leasure
Apache Court Motel 719-471-9440 3401 W. Pikes Peak Ave Colorado & 34th St.	15	$45-$70				•			•	•	AAA rated/pleasing decor/views quiet location, phones, CTV
Best Western Gold Rush Hotel & Casino 209 E. Bennett, Cripple Creek 689-2646	14	Call		2/2					•	•	Private baths/cable TV/queen beds/ Victorian decor
Beverly Hills Motel 632-0386 6 El Paso Blvd., Co Springs, CO 80904	12	$45-$75	•				•		•	•	Near attraction & restaurant horseback riding/BBQ/quiet
Buffalo Lodge 634-2851 800-235-7416 2 El Paso Blvd., Colorado Springs 80904	42	Call	•		Out	•	•		•	•	Rec area & BBQ pits/historic lodge/large groups welcome
Cascade Hills Motel & Cabins 684-9977 At the Entrance to Pikes Peak Highway	17	$30-$70	•			•			•	•	50 Ch Cable TV/Free local calls Mtn setting 5 mi W of Manitou
Cottonwood Court Motel 685-1312 120 Manitou Ave. Manitou Springs 80829	24	$30-$65					•		•	•	Room microwaves & carports / near attractions
Country Inn by Carlson - 800-456-4000 723 US Hwy 24 W, Woodland Park CO 80863	60	Call	•		In	•			•	•	Pikes Peak views/cont brkfst Whirlpool suites / HBO
Cripple Creek Hospitality House 689-2513 600 N B St., Cripple Creek, CO 80813	17	$40-$75				•				•	Elegant rooms/scenic camp-ground/free shuttle to casinos
Dillon Motel 685-5225 Fax:685-1139 134 Manitou Ave., Manitou Springs 80829	18	$38-$79	•		Out				•	•	Playground/ near attractions & restaurants/beautiful view
Eagle Motel 800-872-2285 719-685-5467 423 Manitou Ave, Manitou Spgs CO 80829	25	$45-$75				•			•	•	Manitou's only AAA ♦♦♦ motel attractive, well-kept rooms

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Hotels & Motels

WEST SIDE cont.

Hotel	Number of Rooms	Range of Rates	Kitchenettes/Suites	Restaurants/Lounges	Pool	Hot Tub/Spa	Pets Allowed	Exercise Room	Air Conditioning	Major Credit Cards	Description
El Colorado Lodge 719-685-5485 23 Manitou Ave Manitou Springs CO 80829	26	$44.50-96.50	K		Out				●	●	Adobe style cabins
Falls Motel 719-684-9745 6990 Lake St. Green Mtn Falls CO 80819	12	$40-$65	●			●	●			●	CableTV BBQ/picnic/play area mountain setting by the lake
Garden of the Gods Mtl. Cottages 636-5271 2922 W. Colorado Ave, Co Spgs CO 80904	34	$46-$99.50	●		In				●	●	Newly remodeled/near attractions, dining, mountain views
Holiday Inn Express 1-800-445-3607 601 East Galena, Cripple Creek Colorado	67	Call							●	●	Near casinos, free shuttle free cont'l breakfast, views
The Hotel St. Nicholas 689-0856 303 N. 3rd/Box 1459 Cripple Creek 80813	18	Call	●			●		●		●	Elegant, historic country inn scenic/breakfast/near casino
Imperial Casino Hotel 719-689-7777 123 N Third, Cripple Creek, Colorado	30	$40-$145		3/3		●	●			●	Beautiful historic Colorado Hotel Est. 1896
Lakeside Cottages 684-9576 P.O. Box 478 10535 Foster Ave. Green Mtn Falls 80819	8	$49-$149	●				●			●	1-3 bedroom cottages / some with fireplaces & microwaves
Lofthouse Inn 719-687-9187 222 E. Henrietta Ave. Woodland Park CO	13	$45-$95	●							●	One and two bdrm suites face Pikes Peak, ktchns, prvcy, phn
Maple Lodge 719-685-9230 9 El Paso Boulevard, Co Spgs, CO 80904	20	$40-$130	●		Out				●	●	Deluxe kitchns, 2 wooded ac. near Pikes Pk & Garden of God
Mecca Motel 1-800-634-2442 3518 W. Colorado Ave, Co Spgs, CO 80904	32	$40-$105			Out	●			●	●	Newly renovated/family owned attractions & dining nearby
Mel Haven Lodge 719-633-9435 3715 W Colorado Ave Colo Spgs CO 80904	21	$60-$135	●		Out	●			●	●	Family unit/cable/phones/BBQ playground/laundry/nice view
Midnight Rose Hotel & Casino 689-0303 256 E. Bennett Cripple Creek 800-635LUCK	19	Call	●	3/3					●	●	Modern Victorian styling/ turn-down/cont'l breakfast
Old Colo. City Motel 630-8366 No Smoking 2032 W Cucharras / Senior Discounts	9	Call	●						●	●	Grandpa & Grandma atmosphere /Walk to Old Colo City shops
Our Hearts Inn Old Co City 800-533-7095 2215 W Co Ave. C.S. - Historic area B&B	4	$65-$100	●			●			●	●	Country Victorian Bed&Brkfst hand-stenciled/antiques=cozy
Painted Lady B&B 473-3165/800-370-3165 1318 W Colorado Ave., Co Spgs 80904	4	$70-$115	●			●			●	●	You deserve to be pampered! try this cozy Victorian B&B
Park Row Lodge 685-5216 54 Manitou Ave. Manitou Springs 80829	18	Call	●				●		●	●	Balconies/in-room coffee/on mtn. stream / picnic area
Pikes Peak Super 8 in Manitou Springs 229 Manitou Ave. 80829 800-800-8000	37	Call			Out				●	●	At the foot of Pikes Peak & opposite Garden of the Gods
Rainbow Motel 632-4551 3709 W. Colorado Ave., Co Spgs, 80904	42	$32-$115	●		Out				●	●	Picnic area/ close to Pikes Peak/quiet, clean, comfortable
Raintree Inn West 632-4600 800-929-5478 Hwy 24 & 26th/2625 Oremill Co Spgs 80904	117	$40-$175			In		●		●	●	Near dining/ 4bks S of Old Co City/color tv/15 min most attr
Red Crags B&B 685-1920 or 800-721-2248 302 El Paso Blvd, Manitou Spgs CO 80829	6	$75-$150				●				●	1870's Mansion/all king beds Great views of Pikes Peak
Red Wing Motel 685-9547 800-RED-9547 56 El Paso Blvd., Manitou Spgs CO 80829	27	$30-$69	●		Out				●	●	Near dining, 1 block off Main by S gate Garden of the Gods
Ridgeview Motel 633-6730 3501 W. Colorado Co. Spgs, CO 80904	10	$35-$65	●						●	●	Near attractions, restaurants creekside/patio/comp. coffee
Santa Fe Motel 475-8185 3 Maintou Ave., Manitou Spgs, CO 80829	22	Call	K		Out	●			●	●	Newly renovated/micro fridge cable /southwestern cabins
Silver Saddle Motel 800-S-SADDLE 215 Manitou Manitou Spgs 80829 685-5611	54	Call			Out	●			●	●	Mobile rated/hot tub suites Manitou's finest/ am coffee
Sky Way Motel 719-685-5991 311 Manitou Ave, Manitou Spgs CO 80829	11	$49-$69	●						●	●	At the foot of Pikes Peak swimming, picnicing across st
Spring Creek Inn 685-0852 1222 Manitou Ave, Manitou Springs 80829	31	$40-$120				●			●	●	Picnic area/mountain stream Free local gift certificates
Swiss Chalet 471-2260 3416 W. Colorado Ave., Co Spgs, CO 80904	15	Call	●				●		●	●	AAA/cabins/tree shaded BBQ & picnic area/near restaurants

The area code for the Colorado Springs/Pikes Peak Region is 719.

Hotels & Motels

West (cont.)	Number of Rooms	Range of Rates	Kitchenettes/Suites	Restaurants/Lounges	Pool	Hot Tub/Spa	Pets Allowed	Exercise Room	Air Conditioning	Major Credit Cards	Description
The Timber Lodge 800-448-6762 636-3941 3627 W. Colorado Ave. Co Springs CO 80904	25	$45-$100	●	I/O	Out				●	●	25 cabins 4 acres/stream/12 non kit /fam reunions welcome
Town & Country Resort 800-600-0399 510 N. Hwy 67, Woodland Park, CO 80866	8	$69-$95	●	I/O						●	Charming, modern 2 rm cabin suites nestled in mtn. woods
Treehaven Motel-Cottages 719-471-3390 3620 W. Colorado Ave., Co Spgs, 80904	14	$45-$130	●		Out				●	●	Cozy updated cottages, treed picnic area, phones, TV, 1 acre
Ute Pass Motel 719-685-5171 800-845-9762 1132 Manitou Ave, Manitou Spgs CO 80829	17	$47-$105	●		In				●	●	Surrounded by Fountain Creek clean family-size units, ph/tv
Victor Hotel - 800-748-0870 Fourth St and Victor Ave., Victor CO 80860	30	$68-$99		I/O			●			●	Newly renovated, historical six miles from casinos
Villa Motel 685-5492 1-800-341-8000 481 Manitou Ave, Manitou Springs 80829	47	$39-$90	●		Out	●			●	●	Cable TV/HBO/close to area attractions/newly remodeled
Wheeler House 800-685-2399/719-685-4100 36 Park Ave. Manitou Springs 80829	18	$28-$105	●		Out					●	Peaceful overnight lodging Mtn views. playgrnd across st

Bed & Breakfast (B&B) Inns

Area	Name	No. of Rooms/Suites	Range of Rates	Private Baths	Hot Tub/Tub for 2	Television Available	Fireplace in Room	Major Credit Cards	Description
Central	**Holden House-1902 B&B Inn** 471-3980 1102 W. Pikes Peak Ave. Co Spgs CO 80904	6	$75-$110	All	●	●	●	●	Romantic storybook Victorian-"tubs for 2" fireplaces & more! resident cats AAA/mobil
Central	**Room at the Inn B&B** 719-442-1896 618 N Nevada, Co Spgs 80903 800-579-4621	7	$80-$110	All	●	●	●	●	Elegant 3-story victorian, honeymoon suites romance packages, phones, a romantic retreat
North	**Alpine Chalet Country Inn B&B** 495-9266 11685 Howells Rd., Co Spgs, CO 80908	2	$69-$109	Yes		●		●	Romantic storybook mtn retreat /old world charm/ hospitality / luxurious suite-size rms
North	**Black Forest Bed & Breakfast** 495-4208 11170 Black Forest Rd., Co Spgs CO 80908	4	$75-$125	All	●	●	●	●	Massive log home on 20 treed acres/casual comfort/panoramic views/near town/kids ok
North	**Cross Keys Inn** 481-2772 800-250-KEYS 20450 Beacon Lite Rd Monument CO 80132	3	$65-$100	Yes	●	●		●	Mountain view/full breakfast/rustic log inn located between CoS & Castle Rock
South	**Cheyenne Cañon B&B Inn** 633-0625 2030 W. Cheyenne Blvd., Co Spgs 80906	8	$75-$175	All	●	●	●	●	13,000 ft² mansion secluded in the park each suite a different country - A+ rated
South	**Hughes Hacienda B&B** 576-2060 12060 Calle Corvo Co Springs 80926	1	$85-$100	All	●	●	●	●	Mountain views/Southwest style on 19 acres romantic rooms/10 min. S. of the Broadmoor
South	**Twilight Canyon Inn B&B** 576-7707 2275 Twilight Canyon Tr., Co Spgs 80926	3	$125-$225	All	●	●		●	Gourmet breakfast / secluded 90 acres / elegant Victorian / trails / romantic!
West	**Awarenest Victorian B&B** (719) 630-8241 1218 West Pikes Peak Ave., Co Spgs 80904	1	$75-$90	All		●		●	Traditional Victorian home / stained glass / antiques/clawfoot tub/kids ok/non smoking
West	**Black Bear Inn of Pikes Peak B&B** 5250 Pikes Peak Hwy, Cascade, CO 684-0151	9	$70-$85	All	●	●		●	Romantic new inn/ full breakfast/incredible view / hiking trails / on Pikes Peak Hwy
West	**Eastholme in the Rockies** 684-9901 4445 Haggerman Ave., Cascade CO 80809	7	$59-$125	Yes	●	●	●	●	Awesome mountain setting-minutes to Colorado Springs - 1885 Victorian - Visa MC Disc
West	**Frontiers Rest Bed & Breakfast** 685-0162 341 Ruxton Ave. Manitou Springs CO 80829	4	$75-$100	All		●		●	Historic "old west" Victorian / best location to major attractions / unique themed rooms
West	**Gray's Avenue Hotel** 685-1277 711 Manitou Ave, Manitou Spgs, CO 80829	8	$60-$70	All	●	●		●	Near all attractions /children over 10 please family suites B&B since 1984 1-800-294-1277
West	**The Hosted House, 1894 B&B** 719-632-7569 3001 W. Kiowa Colorado Springs CO 80904	2	$60-$70	All	●	●		●	1894 Storybook Victorian/Sumptuous bkfst/ near Old Colo City/Manitou Spgs/Pikes Peak
West	**Lakeview Terrace Hotel** 719-684-8313 10580 Foster Ave. Green Mtn. Falls 80819	6	Call	Yes		●		●	Historic, elegant B&B/built in 1889/gourmet breakfast / Hosts: Mark & Victoria Marelic
West	**Onaledge B&B** 685-4265 800-530-8253 336 El Paso Blvd., Manitou Springs 80829	5	$80-$130	All	●	●	●	●	Romantic historical victorian / gourmet breakfast/view Pikes Peak/in-room hot tubs
West	**Our Hearts Inn Old Colorado City-Co Spg** Historic Area 800-533-7095 / 719-473-8684	4	$65-$100	All	●	●	●	●	Victorian-stenciled rms/Antq/2 blk to Shops Cottage-cowboy decor/Frpl/Jacuzzi/sleeps 4

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